EFFECTS OF SPLIT ATTENTION ON USING ELECTRONIC TOOLS

By

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by

Naglaa Ahmed Ali

This dissertation is dedicated to:
my lovely mom and dad
and my two brothers, Khaled and Mohamed

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EFFECTS OF SPLIT ATTENTION ON USING ELECTRONIC TOOLS

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Multimedia instruction is widely used in teaching and learning because of its capability of presenting information in different formats. However, the use of multimedia in instruction is not always effective. Some instances of instruction that use multimedia impose a heavy cognitive load on learners, which causes working memory overload and therefore hinders learning. This ineffectiveness may result from inappropriate design of multimedia instruction, which overloads working memory and results in ineffective learning. One of the reasons for this working memory overload is a split attention effect that occurs when learners need to mentally integrate two salient sources of information at the same time in order for the learning materials to be understood.

The purpose of this study is to reduce split attention measured by an achievement test, a task performance test, and a mental effort scale. This study attempted to reduce the split attention effect in multimedia instruction by using different cueing strategies that varied only in the opacity of the text message box (opaque cueing, semi-transparent cueing, transparent cueing).

Results indicated that using semi-transparent cueing was significantly better in reducing split attention in multimedia instruction than each of transparent cueing and opaque cueing.

CHAPTER 1
INTRODUCTION

Statement of the Problem

Multimedia instruction is widely used in teaching and learning because of its potential to present information in different formats at the same time (Guan, 2002). However, according to Mayer and Moreno (2002), the use of multimedia in instruction is not always effective. Some instances of instruction that use multimedia impose a heavy cognitive load on learners, which causes working memory overload and therefore hinders learning (Chandler, Cooper, Pollock, & Tindall-Ford, 1998). This ineffectiveness may result from inappropriate design of multimedia instruction which overloads working memory and produces ineffective learning (Cooper, 1998). Hence, increased attention has been placed on the relationship between the effectiveness of multimedia instruction and the efficiency of various instructional design strategies (Cooper, 1998; Crosby, Iding, & Chin, 2003; Moreno & Mayer, 2000; Sweller, 2004).

According to cognitive load theory (Chandler & Sweller, 1991; Sweller, 1994; Sweller, 1999), the quality of instructional design depends on taking the role and limitations of working memory into consideration. Many uses of multimedia in instruction are ineffective because of a failure to take into account the limited processing capacity of working memory (Chandler & Sweller, 1991, 1992, 1996; Jeung, Chandler, & Sweller, 1997; Paas & van Merriënboer, 1994). Information must be attended to and processed by working memory for encoding into long-term memory (Chandler et al., 1998; Cooper, 1998). If working memory is unable to attend to this information, learning will be hindered (Mayer & Moreno, 2002).

Multimedia instruction consists of more than one source of information (e.g., visuals and their corresponding verbal information). Some of these information sources can be understood only if learners mentally integrate them; that is, in some cases neither visual nor verbal information alone enables understanding (Mayer & Chandler, 2001). In this case, learners need to attend to both visual and verbal sources of information, which impose an extraneous cognitive load in working memory and cause what is known as a "split attention effect" (Chandler & Sweller, 1991, 1992, 1996; Mousavi, Low, & Sweller, 1995; Sweller & Chandler, 1994; Tindall-Ford, Chandler, & Sweller, 1997). Split attention may also occur when presented materials require visual search from the learner (e.g., searching a graphic to locate its salient component) (Jeung et al., 1997).

Numerous causes of split attention have been found when using multimedia as a method of delivering instruction; therefore, different techniques have been used trying to reduce the effect of split attention to achieve more effective instruction. The aims of these techniques are to redesign multimedia instruction to eliminate visual search and other sources of split attention.

Many studies have incorporated techniques to reduce the split attention effect when using multimedia. These studies have included research applying animation and voice-over, animation and text, still images and text, still images and audio, and so forth (Tabbers, 2002). Other studies attempted to reduce the split attention effect by physically integrating the text and the visual that need to be mentally integrated (spatial contiguity effect) (Chandler & Sweller, 1991, 1996; Mayer, 1999; Tarmizi & Sweller, 1988). The rationale of the spatial contiguity effect is to help learners easily find the verbal information and its corresponding visual information with minimal visual search (Mayer, 1999). This spatial contiguity effect is also known as the "proximity effect". Wickens and Carswell (1995) and Yeh and Wickens (2000) stated that the greater the need to integrate more than one source of information for the presented materials to be understood, the greater the need of displaying them in proximity to one another. The closer they are to each other, the less time and cognitive load are required to process these sources of information.

Some other studies tried to reduce the split attention effect by presenting visual and verbal information simultaneously rather than successively (temporal contiguity effect) (Mayer & Anderson, 1991, 1992; Mayer & Moreno, 1998; Mayer, Moreno, Boire & Vagge, 1999; Mayer & Sims, 1994). The rationale of the temporal contiguity effect is that learners better understand the presented materials when they do not have to hold all visual information in working memory until the corresponding verbal information is presented or vice versa (Mayer & Moreno, 2002). Different studies (Mayer, 2001; Moreno & Mayer, 1999) tried to reduce split attention by replacing the on-screen text with audio or by adding visual or speech cues to minimize visual search (Jeung et al., 1997; Kalyuga, Chandler, & Sweller, 1999; Mautone & Mayer, 2001; Tabbers, 2002). Most of these studies were successful in reducing split attention by reducing the spatial distance between text and visuals, replacing the text component with audio, or using cues to reduce visual search.

All the studies that attempted to reduce split attention dealt with explanatory information (scientific concepts) rather than procedural information (for example, showing students how to build a webpage using Dreamweaver or how to create a PowerPoint presentation). The procedural information requires more visual search while studying it because visual search involves many steps and eye movements from one component of the visual to another. None of these studies used visual cues in the form of a text message box.

This study attempted to reduce the split attention effect caused by the visual search required of the learner by using visual cues in the form of text message boxes while learning how to build a webpage using Dreamweaver or how to create a PowerPoint presentation. The rationale for using text message boxes is to minimize visual search and to provide all critical information at the same time. However, using these visual cues in the form of text message boxes may overload working memory.

Moreover, the possibility exists that using text message boxes (opaque background) could obscure portions of the visual material that the learner needs to see, thus causing the learner's attention to focus on the text and ignore the visual elements of the message. In this case, the text message box serves as a cue to focus the learner's attention on the text, producing a split attention effect. This issue was addressed by Harrison, Ishii, Vicente, and Buxton (1995a):

> When there are multiple sources of information we must make choices about what to attend to and when. At times, we need to focus our attention exclusively on a single item without interference from other items. At other times, we may need to time share or divide our attention between two or more items of interest. (p. 317)

According to Harrison et al. (1995a), learners' attention can be enhanced by instructional design choices. For example, opaque overlapping window designs hinder divided attention but facilitate focused attention. In addition, using an opaque background for the text message boxes may facilitate split attention because the text and the visuals are not presented at the same time thus resulting in a successive presentation rather than a simultaneous one.

The purpose of this study was to examine the effects of different text cues on reducing split attention measured by an achievement test, a performance test, and a mental effort scale. This examination was done by varying the background opacity (opaque, semi-transparent, transparent) of the message boxes in multimedia instruction. In addition, this study compared the learning outcomes of students who scored low or high on measures of spatial ability. According to Mayer and Sims (1994), spatial ability is considered one of the most significant cognitive abilities that affect learning. High-spatial-ability students may be able to keep an image active in working memory in the absence of the visual and make better connections between the visual and verbal information than low-spatial-ability students, according to Mayer and Sims (1994).

Purpose of the Study

The primary focus of this study was to reduce the split attention effect in multimedia instruction by using a new cueing strategy. This cueing strategy used three different opacities (opaque, semi-transparent, transparent) for the text message boxes. Several studies (Harrison & Vicente, 1996; Irani & Iturriaga, 2002) investigated the effects of different transparency on text legibility and on selection response times and error rates. A study by Irani and Iturriaga (2002) investigated whether or not a transparent background of the text label on 3D-shaded diagram elements can result in better readings of the text and nodes in the diagrams. The results of this study indicated that using a transparent background on the labels improved text legibility and maintained node visibility at the same time. Yet none of these studies addressed this issue either in multimedia instruction or its effectiveness in reducing split attention.

The purpose of this study was to examine the effects of different text cues that vary in the background opacities (opaque, semi-transparent, transparent) of text message boxes in multimedia instruction on reducing split attention measured by an achievement test, a performance test, and a mental effort scale on low- and high-spatial-ability students. To make the study more robust, this study involved two experiments using two different topics: how to build a webpage using Dreamweaver and how to create a PowerPoint presentation.

Significance of the Study

The potential significance of this study can be seen in the following ways:

1. It can contribute to the body of knowledge of alternative methods of reducing split attention effect in multimedia instruction.
2. It can contribute to an emerging set of design principles and how research in instructional design can contribute to cognitive load theory.
3. It can offers potential strategy for improving both cognitive load theory and educational practices.
4. It can provide guidance for the development of effective multimedia instruction.
5. It can contribute and enrich research in multimedia and in the use of different opacities as an instructional design strategy in designing multimedia instruction.
6. It can provide strategies and techniques in how to design multimedia instruction to reduce split attention between two or more pieces of information and to enhance performance.
7. It can offer conceptual framework for instructional multimedia designers.

Definition of Selected Terms

For the purpose of this study, the following term definitions are used:

Multimedia is computer-based instruction that consists of both visual and verbal components.

Verbal information refers to any format of a verbal component being used in multimedia instruction (audio and/or on-screen text).

Working memory is a system for temporarily storing and processing information needed in the execution of cognitive tasks (Baddeley, 1986). Working memory is known for its limited capacity.

Split attention is the need to attend to more than one source of information simultaneously.

Spatial contiguity effect occurs when pictures and their corresponding text are placed near each other on a computer screen or printed page.

Temporal contiguity effect occurs when pictures and their corresponding text are presented simultaneously rather than successively.

Visual search is the search for the desired item among different distracters.

Transparency is when an object is superseded by other objects but can still be seen behind or through them.

Semi-transparency is the state between full opacity and full transparency.

Opacity is the opposite of transparency; it is the complete blocking out of an object by other objects.

Text message box is the container that contains the explanation text for a visual on the screen.

Visual cues are what is added to instruction for attracting attention, creating emphasis, or adding explanation.

Spatial ability is the ability to mentally rotate or fold objects and imagine the changing configurations of these objects that would result from this handling.

Research Hypotheses

Many studies have used different strategies to reduce the split attention effect in multimedia instruction. However, none of these strategies measured the effect of using different opacities for the background of the text message boxes on reducing split attention in multimedia instruction. This study examined the effects of different background opacities (opaque, semi-transparent, transparent) of the text message box in multimedia instruction on reducing split attention measured by an achievement test, a performance test, and a mental effort scale on low- and high-spatial-ability students. This study contained nine hypotheses:

1. There is no significant difference among all subjects in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect measured by an achievement test (Experiments 1 and 2).
2. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among low-spatial-ability students measured by an achievement test (Experiments 1 and 2).
3. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among high-spatial-ability students measured by an achievement test (Experiments 1 and 2).
4. There is no significant difference among all subjects in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect measured by a task performance test (Experiments 1 and 2).
5. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among low-spatial-ability students measured by a task performance test (Experiments 1 and 2).
6. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among high-spatial-ability students measured by a task performance test (Experiments 1 and 2).

7. There is no significant difference among all subjects in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect measured by a mental effort scale (Experiments 1 and 2).

8. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among low-spatial-ability students measured by a mental effort scale (Experiments 1 and 2).

9. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among high-spatial-ability students measured by a mental effort scale (Experiments 1 and 2).

Limitations of the Study

The following limitations should be taken into account before the results of this study are generalized in any way:

1. Because the present study utilized only a limited age range, the results can be generalized only within that age range.
2. Most of the participants in this study were female.
3. The study was limited by the number of the participants.
4. The content of the multimedia instruction was procedural information (how to build a webpage using Dreamweaver and how to create a PowerPoint presentation). Different results might be observed if different topics were involved.

CHAPTER 2
LITERATURE REVIEW

Cognitive Load Theory

Cognitive load theory (Sweller, 1988, 1994, 1999; Sweller, van Merriënboer, & Paas, 1998) refers to the amount of mental effort or mental activities required by working memory (Cooper, 1998). This theory addresses the role of working memory in the learning process and takes into consideration the limitation of working memory when faced with new information entering via sensory memory (Sweller, 2004). Cognitive load theory also addresses the interaction between new information and cognitive structures and the implications of that interaction when designing instruction (Kalyuga et al., 1999).

According to cognitive load theory, the effectiveness of learning materials is determined by the mental load placed on working memory. Mental load is the part of cognitive load that is imposed entirely by the task and the subject characteristics (Paas & van Merriënboer, 1994). If the amount of mental load exceeds the limit of working memory, the learning will be overburdened (Chandler et al., 1998). This theory assumes that information presented to learners should be organized in a way that reduces working memory overload and facilitates the process of acquiring new schemas (Kalyuga et al., 1999; Sweller, 1994). The following section highlights the characteristics and the structure of working memory and its relationship with cognitive load theory to better understand the theory and its applications in designing instruction, especially multimedia instruction.

Working Memory and Cognitive Load Theory

Previously, memory was thought of in terms of long-term and short-term memory (Miller, 1956). Now, short-term memory is known as "working memory" (Baddeley, 1992). According to Simon (1974), working memory is the place where mental activities occur with limitation in capacity (Miller, 1956) and duration (Peterson & Peterson, 1959). The capacity limitation of working memory means only a limited amount of information can be processed at the same time (when there are too many elements of information that need to be processed by working memory at the same time, this information cannot be processed adequately) (Cooper, 1998). The duration limitation of working memory means information can be held only for a limited amount of time. Working memory was initially perceived as one unit, but it now consists of multiple stores or channels (Baddeley, 1992, 1997; Pavio, 1986; Penney, 1989). Various researchers have attempted to explain the function of the multiple stores.

Pavio's (1986) dual coding theory assumed that information is processed using two different stores or channels, one for verbal information and one for visual information. The two stores are linked, and the memory performance may be enhanced if the information is processed using the two channels at the same time (e.g., the presented information consists of verbal and visual information, which is the case in multimedia instruction). Penney (1989) indicated that visual text and audio information are processed in two different processors. Baddeley (1986, 1992, 1997) divided working memory into three processors; visuo-spatial sketchpad for processing visual information; a phonological loop for processing verbal information; and a central executive as a coordinator.

In summary, the new structure of working memory basically consists of more than one channel or processor, one for processing the visual information and the other one for processing the verbal information. A major result of this construction of working memory and its limitation in capacity and duration is that working memory must be considered as a critical factor when designing educational materials (Paas & van Merriënboer, 1994; Tindall-Ford et al., 1997). The following section highlights the sources that cause working memory overload and result in ineffective learning.

Sources of Cognitive Load

Two different sources of cognitive load are: intrinsic and extraneous (Sweller & Chandler, 1994). Intrinsic cognitive load is established by the complexity of the learning materials (the degree of interactivity between learning components) (Cooper, 1998). Some learning materials can be processed independently as a single unit—low interactivity—and some cannot be processed independently from other components—high interactivity (Sweller & Chandler, 1994). The higher the interactivity between learning components, the more complex the learning materials become and the more the cognitive load is imposed on working memory. The intrinsic cognitive load cannot be modified by the instructional design of instructional materials; however, extraneous cognitive load can be changed by the instructional design options (Cooper, 1998). Both intrinsic and extraneous cognitive loads affect working memory and contribute to the total cognitive load imposed by learning materials (Leahy, Chandler, & Sweller, 2003).

Instructional materials can be presented in different ways, and each way has a different extraneous cognitive load. Instructional materials that have low extraneous cognitive load or try to reduce the extraneous cognitive load are more effective than instructional materials that impose high extraneous cognitive load (Chandler et al., 1998).

Mayer and Moreno (2003) addressed three types of cognitive processes that working memory performs when faced with new information. These three cognitive processes form the total extraneous cognitive load: essential processing, incidental processing, and representational holding. Essential processing is the method of making the presented materials intelligible by choosing words and images, organizing them, making connections between them, and finally integrating them with each other and with prior knowledge from the long-term memory. For example, presenting materials as pictures and on-screen text may overload the visual working memory, which results in a failure of organizing and making connections between pictures and on-screen text (split attention effect). Incidental processing is the process of making some of the presented materials unintelligible. For example, adding interesting elements to the instructional materials (e.g., background music, which is the coherence effect and presenting the verbal information as both on-screen text and narration, which is the redundancy effect) may increase the incidental process as learners dedicate a part of working memory capacity to process these extra materials. Moreno and Mayer (2000) tested this incidental process. In their study they compared animation presented with concurrent narration versus animation presented with concurrent narration, background music, and other sounds. Results of this study indicated that students were able to understand multimedia instruction when the auditory channel of working memory is not swamped with extra elements. Representational holding is the process of keeping a mental representation in working memory for some time, for example, presenting the text message in a window that overlaps the visual information, placing the text far from its corresponding visual, or presenting the verbal and visual information successively rather than simultaneously. The learner in these situations cannot see the verbal and its corresponding visual at the same time, which requires keeping an image of the visual information in working memory while reading or listening to the verbal information or vice versa. Also placing the text information far from its corresponding visual causes the learner's engagement in visual search to figure out which part of the visual corresponds with the words (Mayer & Moreno, 2003).

Sweller (2004) addressed the need to design instructional materials in a way that reduces cognitive load by reducing the sources that cause working memory overload.

> Cognitive load theory both provides instructional design principles that would be difficult to devise without its particular view of human cognitive architecture and throws lights on that architecture. . . . Discovering that some instructional designs are superior to others can provide insights into human cognitive architecture that may otherwise be difficult to achieve. (p. 9)

In summary, cognitive load theory provides both explanations for the failure of some uses of multimedia in instruction to facilitate learning and guidelines to develop instructional designs that adopt the limited capacity of working memory (Kalyuga et al., 1999). The following section highlights some of the ways used to reduce or eliminate cognitive load in multimedia instruction.

Reducing Cognitive Load

Mayer and Moreno (2003) provided nine ways to reduce cognitive load in multimedia instruction: offloading, segmenting, pre-training, weeding, signaling, aligning, eliminating redundancy, synchronizing, and individualizing. Taking these ways of reducing the level of extraneous cognitive load into consideration when designing instructional materials may facilitate learning. A summary is now provided for these nine ways of reducing cognitive load.

The offloading strategy (changing the sensation of getting verbal information from a visual format to an auditory format—also known as the "modality effect") is used to reduce cognitive load. This cognitive load is caused by overloading the visual working memory when presenting verbal information as on-screen text along with visual information. The offloading strategy replaces the on-screen text with audio to reduce the visual working memory load.

The segmenting strategy is used to reduce cognitive load caused by overloading visual and auditory working memory when presenting instructional materials as one long segment, which allows no time for the learners to make connections between the visual and verbal information. The segmenting strategy divides a long presentation into small segments. After finishing every segment, learners have time to make connections between the verbal and visual information and get ready for the next segment.

Pre-training is also used to reduce cognitive load caused by overloading the visual and auditory working memory in which learners receive pre-instruction about the component of the topic to be learned. It is an alternative way to segmenting.

Weeding (coherence effect) is used to reduce cognitive load caused by overloading working memory when adding interesting elements to the instructional materials (e.g., background music). The weeding strategy presents instructional materials as coherently as possible by eliminating interesting extraneous elements and including only salient information.

Signaling (cueing) is used to reduce cognitive load caused by overloading working memory due to the visual search that sometimes is required from learners while learning the instructional materials. The signaling strategy provides cues to the learners about how to select and organize the presented materials.

Aligning words and pictures is used to reduce cognitive load caused by overloading the visual working memory when the materials require the learner to engage in a visual search. This visual search occurs when placing the text far from the pictures or placing the text and its visual component into two separate windows. The aligning strategy presents text and visual information near to each other.

Eliminating redundancy is used to reduce cognitive load caused by overloading the visual and auditory working memory when presenting the identical verbal information as on-screen text and narration. The eliminating redundancy strategy reduces cognitive load by eliminating one of the two ways of presenting the verbal information where a source of verbal instruction or a source of visual instruction alone provides full intelligibility (Cooper, 1998).

Synchronizing is used to reduce cognitive load caused by overloading working memory, which is created by presenting the visual and verbal information successively. This requires working memory to keep a mental representation of one information source until the other is presented. The synchronizing strategy reduces cognitive load by presenting the verbal and visual information simultaneously rather than successively.

Individualizing is an alternative way to reduce cognitive load caused by successive presentations. It is a substitute to synchronizing. The individualizing strategy provides high-spatial-ability and low-spatial-ability learners with different presentations.

Drawing from the previous strategies, cognitive load theory is an important component in any theory of learning that is anticipated to guide in the design of multimedia instruction (Mayer & Moreno, 1998). Instructional materials that utilize multimedia should be designed to minimize the overloading of the learner's cognitive system (Mayer & Moreno, 2000). One of the most common sources of causing cognitive load in multimedia instruction is the split attention effect (Chandler & Sweller, 1991, 1992, 1996; Mousavi et al., 1995; Sweller & Chandler, 1994; Tindall-Ford et al., 1997). The following section highlights the meaning of split attention, sources of split attention, and ways to reduce the split attention effect in multimedia instruction.

Split Attention Effect

Researchers have defined "split attention" as the hindrance of learning that happens when it is necessary to mentally integrate more than one source of information before the instructional materials become understandable (Chandler & Sweller, 1992; Ward & Sweller, 1990). In other words, split attention happens when the learner needs to attend to and mentally integrate more than one source of information (one source of information is intelligible in isolation). This need for integrating more than one source of information imposes cognitive load on working memory and therefore hinders learning (Sweller, 2004).

Sources of Split Attention

According to the cognitive load theory, learning might be hindered when learners need to attend to and mentally integrate more than one source of information, which might overload the limited working memory capacity (Kalyuga et al., 1999). The following different examples of split attention occur when learners need to attend to two sources of information and mentally integrate them for understanding.

Chandler and Sweller (1992) proved that a split attention effect happens when reading an experimental paper where the results portion and the discussion portion are in different sections. The results and discussion sections need to be integrated for better understanding of the results and their implications. Hence, split attention may be decreased when integrating the results and discussion sections into one section.

Also, split attention occurs when the visual and its corresponding textual information are placed far from each other. For example, studies have shown that the physical integration of textual and visual information resulted in improved test scores (Bobis, Sweller, & Cooper, 1993; Cerpa, Chandler, & Sweller, 1996; Chandler & Sweller, 1991, 1992; Kalyuga et al., 1999; Mousavi et al., (1995); Mwangi & Sweller, 1998; Sweller, Chandler, Tierney, & Cooper, 1990; Tarmizi & Sweller, 1988). These studies demonstrated that when a text box is placed next to its corresponding picture, the need to mentally integrate the text and the picture is reduced (the time needed to keep the picture in working memory until searching for its corresponding text is decreased), resulting in a lower extraneous load and facilitating the learning process.

Split attention may also occur when the task requires the learners to do different activities at the same time. For example, when learning software using a manual that provides step-by-step instructions, the learning task requires learners to split their attention between the printed materials and the computer screen (Cooper, 1998). One way to eliminate the split attention between the manual and the computer screen would be to provide a manual that contains all the required information and eliminates the use of the computer. In a study by Chandler and Sweller (1996), the manual-only group (that completed the software training without using the computer) outperformed the group that had used the manual and the actual software at the same time when testing students in their performance on a computer with the actual software. Another way to eliminate split attention is to develop computer-based tutorials that integrate text-based instructions into a computer simulation of the software that needs to be taught, which eliminates the need for the manual. Learners therefore do not have to split their attention between the manual and computer screen (Cerpa et al., 1996).

Another cause of split attention is visual search (Crosby et al., 2002): "Visual search is the cognitive process of finding particular data within a visual field" (p. 134).

Visual search means only the visual channel is being overloaded (Sweller, et al., 1998). For example, when searching software to locate a component or visually scan the graphic to relate the graphical component to its corresponding verbal, a split attention effect occurs. Hegarty and Just (1989) demonstrated that learners read a part of the verbal information and then look for its corresponding visual information. When the verbal information is placed far from its corresponding visual, learners in this case are required to use some of working memory cognitive resources to visually scan the graphic. Split attention can be reduced in different ways (Mayer & Moreno, 2003). The following section is a summary of ways used to reduce the split attention effect in multimedia instruction.

Reducing Split Attention

Contiguity effect

The contiguity effect is built on the assumption that learners make better connections between visual and verbal information not only when they are presented near to each other in space but also in time (Moreno & Mayer, 1999). Mayer (1999) proposed two different contiguity effects: a spatial contiguity effect and a temporal contiguity effect.

Spatial contiguity effect. The spatial contiguity effect shows that learners make better connections between textual and visual information when they are placed in proximity. When the visual and textual information are placed near to each other, learners do not have to keep a mental representation of the visual information in working memory while searching for its corresponding textual information, which minimizes the visual search. Many studies (Mayer, 1997, 2001; Mayer & Moreno, 1998, Mayer, Steinhoff, Bower, & Mars, 1995; Moreno & Mayer, 1999) addressed this effect and proved that students perform better in different tests when textual information and its corresponding visual information are near each other on a page or on a computer screen.

Temporal contiguity effect. According to the information delivery theory presenting the instructional materials, two different times are better than presenting it one time. In this case, presenting the verbal and visual information concurrently means that learners receive the instruction one time, but presenting them successively means that learners receive the same instruction two times (Mayer & Moreno, 1998). But this is not the case if the visual and verbal information are salient.

The temporal contiguity effect shows that learners are better able to make connections between salient verbal and visual information when they are presented at the same time rather than at different times (simultaneously rather than successively). When the visual and verbal information are presented at the same time, learners do not have to keep a mental representation of the entire verbal information in working memory until the corresponding visual information is presented and vice versa (Mayer, 1999; Mayer & Moreno, 2003). Also, learners are to build connections between corresponding visual and verbal information more easily when both are presented in working memory simultaneously. Many studies (Mayer & Anderson, 1991, 1992; Mayer & Moreno, 1998; Mayer et al., 1999; Mayer & Sims, 1994) addressed the contiguity effect and proved that students understand multimedia explanations better when verbal information and its corresponding visual information are presented simultaneously rather than successively. These studies compared animations and narrations (or on-screen text presented simultaneously) versus animation and narration (or on-screen text presented successively).

Modality effect

The modality effect (Mayer, 2001; Sweller et al., 1998) is the elimination of split attention by using audio instead of on-screen text in multimedia instruction (Kalyuga et al., 1999). Using different modalities (audio and pictures instead of on-screen text and pictures) to present the instructional materials may decrease working memory overload by using two different channels (senses) instead of one (Mousavi et al., 1995; Chandler & Sweller, 1992; Kalyuga et al., 1999). The modality effect can be achieved when two sources of information are unintelligible in isolation and must be mentally integrated before they can be understood. It cannot be achieved by randomly presenting some material in auditory form and some in visual form or by presenting the same material in both written and spoken form (Sweller, 2004).

Mayer's (1997) generative theory of multimedia addressed the assumptions of the dual processing theory concerning the advantages of using different channels or modalities in processing information.

- Working memory is divided into two different channels: the visual channel and the audio channel (Baddeley, 1992).

- Each working memory has limited capacity, and the amount of processing that can take place with each channel is limited (cognitive load theory) (Baddeley, 1992; Sweller, 1999; van Merriënboer, 1997).
- Meaningful learning occurs when learners are able to attend to both verbal and visual information, make connections between them, and integrate them with each other and with prior knowledge from the long-term memory (Mayer, 1999, 2001).
- Connections can be made only if the verbal and visual information are in working memory at the same time (Clark & Paivio, 1991; Paivio, 1986).

According to the dual processing theory (Clark & Paivio, 1991) when presenting verbal information as text, it is processed initially in the visual channel with the visual information, which may overload the visual working memory. Learners then fail to make connections, which therefore hinders learning. However, when presenting the verbal information in an auditory format, it is processed initially in the audio channel, which may decrease working memory overload and facilitate learning (Mayer & Moreno, 2003). Also, when presenting verbal information in the form of text along with visual information, students may pay full attention to the text, which results in missing some part from the visual information. If they pay full attention to the visual information, however, they may miss some part of the text. In this case, the verbal and visual information may be processed successively because they are not in working memory at the same time. Many studies (Jeung et al., 1997; Mayer & Moreno, 1998; Moreno & Mayer, 1999; Mousavi et al., 1995; Tindall-Ford et. al., 1997) provided evidence of the modality effect that students understand the multimedia instruction better if the verbal information is presented in the audio format instead of on-screen text.

Redundancy effect

Redundancy means repeating the same information in different formats. There are many different forms of redundancy. First, a redundancy may occur when a selfexplanatory diagram has additional text to describe it (Chandler & Sweller, 1991). Second, a redundancy may occur when learning a computer software program using a manual that has text and visual explanations and using the actual software at the same time (Cerpa et al., 1996; Chandler & Sweller, 1996; Sweller & Chandler, 1994). Finally, a redundancy may occur when the same material is presented simultaneously in written and spoken format (Kalyuga et al., 1999; Kalyuga, Chandler, & Sweller, 2000; Mayer, Heiser, & Lonn, 2001). In other words, if one source of information (visual or verbal) is intelligible in isolation, providing the same information in a different format will impose extraneous cognitive load. Working memory resources will need to be used to process the additional material that is not needed for understanding.

Cueing effect (signaling)

Cueing is a technique used to reduce split attention effect caused by visual search, which is required in studying some instructional materials (Mauton & Mayer, 2001). Cueing or signaling strategies were used first in printed materials (typographical cueing), such as bolding, italics, underline, and use of color-coding, to guide the search for specific information and to connect relevant information by making it distinguishable from other text (Lorch, 1989; Meyer, 1975). One of the reasons explaining why cueing might contribute to more effective instruction concerns how using cueing can reduce working memory overload. Britton, Gylnn, Meyer, and Penland (1982) found that cued text requires less mental load to process than non-cued text. Cueing assists learners to easily find related information using limited working memory cognitive resources. This assumption is proved by Loman and Mayer (1983): Students in the cued text group recalled significantly more related concepts and generated deeper answers to the transfer problems.

The effects of cueing strategies were not only measured in printed materials but also were measured in multimedia instruction as well. According to cognitive load theory (Sweller et al., 1998) and Mayer's generative theory of multimedia learning (Mayer, 2001), adding visual cues that connect elements of a picture to the text increases the effectiveness of multimedia instruction in terms of better learning results and/or less mental effort.

This effect of cueing strategies was demonstrated by different studies (Jeung et al., 1997; Kalyuga et al., 1999). In a study by Kalyuga et al. (1999), color-coding techniques were used to reduce split attention. In their study, if the textual explanation of the diagram was selected, the relevant parts of the diagram would turn to the same color as the text. Results indicated that the color-coded group demonstrated a lower rating of learning difficulty, which is an indication of reduced working memory load. Also, this group demonstrated significantly higher performance. The learning difficulty scale served as evidence that the difference in performance is caused by cognitive load aspects. According to these results, Kalyuga et al. (1999) suggested the use of color-coding as an alternative to physically integrating text and visual information to reduce split attention. They also addressed the importance of caution in using colors because using too many colors at the same time may overload working memory.

Another study conducted by Jeung et al. (1997) showed that replacing visual text with audio does not always improve the effectiveness of multimedia instruction, especially when pictures are high in visual complexity. But by adding visual cues to the pictures to relate the right elements in the picture to the accompanying spoken text, the modality effect is recovered in terms of a shorter time on problem-solving. Tabbers, Martens, and van Merriënboer (2001) tested the generalizability of the cueing effect in classroom settings. Two groups studied a web-based multimedia lesson on instructional design for about an hour. They then completed retention and transfer tests. Results indicated that adding visual cues to the pictures resulted in higher retention scores.

Previous studies tested the effect of using cueing when using text in printed materials or still pictures in multimedia instruction. These studies found a positive effect in enhancing instruction (Loman & Mayer, 1983; Lorch & Lorch, 1996). But thus far only a few studies focused on the effect of using cueing strategies when using animation on multimedia instruction. These multimedia studies provided some interesting contrasting results. One of those studies (Huk, Steinke, & Floto, 2003) was conducted to measure the effect of using cues in computer animations, as well as on learners' spatial ability. This study showed that low-spatial-ability learners had more problems in understanding the computer animation than learners with high spatial ability. This study also found that the educational value of computer animations can be enhanced by adding visual cues in learners with high as well as low spatial ability.

A study by Mautone and Mayer (2001) showed that using cueing with animations enhanced problem-solving ability. This study involved three experiments and was conducted to measure the effects of cueing in three different kinds of instructional messages: instruction presented in verbal form as a text passage; instruction presented in verbal form as speech; and instruction presented in verbal and visual form as a narrated animation. The purpose of Experiment 1 was to determine whether or not adding cues to a text message would improve students' understanding. Students who received cued text were better in recalling than did students who received non-cued text, but the difference was not statistically significant. Also, students who received cued text generated significantly more acceptable answers on the transfer test than did students who received non-cued text. The purpose of Experiment 2 was to determine whether or not speech message cueing would improve students' understanding. The speech group performed significantly better in recalling than did the non-cued speech group. Also, students who received cued speech generated significantly deeper answers on the transfer test than did students who received non-cued speech. The purpose of Experiment 3 was to determine whether or not cueing a multimedia message (narrated animation) would improve students' understanding. As in Experiment 2, the narration was either cued or non-cued. Also, the animation was either cued or non-cued. Animation was cued by using colored arrows. Students who received both kinds of cueing were not significantly different in recalling on the retention test than students who received neither kind of cueing. The cueing did not add any additional content information but helped clarify the structure of the passage. Students who received signaling generated significantly more solutions on the transfer test than did students who did not receive signaling when the explanation was presented as printed text (Experiment 1), spoken text (Experiment 2), and spoken text with corresponding animation (Experiment 3). Mautone and Mayer (2001) explained the failure of obtaining an animation cueing effect to: (a) a weak treatment (the use of colored arrows and icons did not adequately guide learner processing); (b) the possibility that the animation itself was not complex and did not need to be cued; or (c) the possibility that learners are more skilled in processing cues from text than from pictures.

Visual Attention

Egeth and Yantis (1997) defined visual attention as selecting places and objects for processing. The following section highlights two different kinds of attention: focused and divided attention and the relationship between visual attention and visual design.

Focused and Divided Attention

In divided attention, multiple stimuli placed in different locations are processed at the same time but in focused attention, only one stimulus is processed at a time (Valdes-Sosa, Cobo, & Pinilla, 2000). The need for focused or divided attention is determined by the nature of the task required from the learner. However, the ability to successfully focus or divide attention can be enhanced by the display design characteristics (Harrison et al., 1995a). For example, opaque overlapping window designs do not facilitate divided attention (some information cannot be seen) but facilitate focused attention

According to Harrison et al., (1995a):

> The level of transparency affects the visibility of the background. Low degrees of transparency (more opaque) distinguish the appearance of the foreground and background object, allowing the user to easily focus attention on the foreground. For divided attention, a high degree of transparency is desirable to support higher visibility of both layers. (p. 317)

Some examples for focused and divided attention (Harrison et al., 1995a) include:

Focused attention examples:

- A pop-up window appears while working in a document.
- A pull-down menu that covers the current window for a while.

Divided attention examples:

- Using the color palette and seeing the changes of the color selection in the document.
- Video conference with a partner and looking at a video screen and the work in progress at the same time.

Visual Attention and Cueing

According to Nagy and Thomas (2003), cues are effective for direct attention to related stimuli and neglecting unrelated stimuli. Palmer (1994) supported this assumption by showing that learners could concentrate on stimuli at cued positions and neglect stimuli at non-cued positions. Tsal and Lavie (1988) suggested that color may be used to cue targets to which attention needs to be guided. Color-coding literature suggests that color also may be used to direct attention to certain stimuli and, therefore, decrease the visual search process. Different studies have proved this assumption. Egeth, Virzi and Garbart (1984), Friedman-Hill and Wolfe (1995), Kaptein, Theeuwes, and van der Heijden (1995), and Kim and Cave (2001) showed that the distracters having the same color as the target stimulus received more attention than the distracters with different colors from the target stimulus. Harms and Bundesen (1983) found that distracters with the same color as the target were selected with the target, even though the distracters were unrelated to the task. This proves that object-based attention extends to groups of objects that share some features such as color.

Many studies (Downing & Pinker, 1985; LaBerge & Brown, 1989) were conducted to examin the relationship between attention strength and the distance between the stimuli and the cues. Also, Egly, Driver, and Rafal (1994) used two rectangles and a spatial cue that appeared at the end of one of the rectangles. Responses to the stimulus at the cued position were faster than responses to the stimulus at the non-cued positions of the same rectangle, which confirms attention weakens with distance from the cue.

Visual Attention and Visual Design (Opacity)

As previously mentioned, the split attention effect can be reduced by placing the text and its corresponding visual in proximity to each other. As two stimuli are brought closer together, dividing attention between them becomes easier (Valdes-Sosa et al., 2000). The proximity compatibility effect not only depends on how close two sources (text and visual) are to each other but how similar the sources are. Therefore, two sources are in proximity if they are close together in space, have the same color, and use the same physical dimensions (Wickens & Carswell, 1995).

Several ways can manipulate the physical characteristics of two or more displayed information sources in order to create the proximity closeness. Many of these ways were stimulated by the Gestalt laws of perceptual organization, including proximity, similarity, area, and closure (Pomerantz & Kubovy, 1986). The following methods are used to achieve proximity (Wickens & Carswell, 1995).

First, proximity can be increased by increasing the spatial proximity of the information. Second, proximity can be increased by adding cues that provide connections between the two sources of information. Third, proximity can be increased by using source similarity, which might be implemented by making all information sources the same color. Fourth, proximity can be increased by the homogeneousness of the sources of information in which each source is coded using the same characteristic (e.g., length, orientation, brightness). A final way of achieving proximity is by object integration (Bennett & Flach, 1992; Carswell, 1992) in which the information sources are arranged in a way to appear to be part of one object. Closeness in space, sharing the same color, and cueing two sources could make their assimilation easier because of the decrease in visual search and time to go from one source to another (Wickens & Carswell, 1995).

This study provided another approach of achieving proximity in a way that reduces cognitive load and reduces the split attention effect in multimedia instruction. It is trying to achieve this proximity by using cues to minimize the visual search required from the students while learning the instructional materials. The cues used in this study are in the form of text message boxes that help minimize the visual search accompanied by the instruction (the instruction is in the form of animation with narration), and these cues provide critical information at the same time. Cues are used to connect the narration with its corresponding part and to present some critical information at the same time. For example, when the narration mentions the Properties Window in the Dreamweaver interface, a text message box appears and points to the Properties Window.

Using these cues may block some visual information because the text message box is opaque. This study used different text message boxes with different opacities to measure their effects on achievement, performance, and mental load. The rationale is that better achievement, performance, and less mental load may be achieved if the text information did not block the visual information. Using transparent or semi-transparent text message boxes allows the appearance of the visual information while reading the text. In this case, students are not required to hold the verbal information in their working memory until the appearance of the visual information which allows the processing of visual and verbal information in working memory at the same time. The rationale of using transparent or semi-transparent background for the text message boxes can be summarized as follows:

Placing the text messages in a transparent or semi-transparent box may increase the proximity effect (perceptual and spatial). The text message and visual message appear more as one object, and the divided attention between visual and text becomes easier producing a decrease in the visual search between the text and the visual component.

Also, using transparent or semi-transparent background for the text message boxes allows the text to be as close to its visual part as possible without blocking the visual. This results in reducing visual search, cognitive load, and split attention between the text and the visual information. According to Zhai, Buxton, and Milgram (1996), a semi-transparent surface does not completely block the view of any object because it permits the user to maintain awareness of the background information.

Placing text messages in an opaque box may serve as a cue for fully focusing attention on the text and ignoring the visual, resulting in successive presentation of the information rather than the simultaneous one. According to Harrison, Kurtenbach, and Vicente (1995b), to facilitate focused attention (ignoring information from the background layer while focusing on the foreground), the attributes of the information on foreground objects should be as different as possible from the background. In contrast, to facilitate divided attention, there is need to see through the object in the foreground (more transparency).

Spatial Ability

Recent researchers have identified situations in which multimedia instruction can be effective (Mayer, 1997, 2001; Mayer & Moreno, 1998; Mayer & Sims, 1994; Moreno & Mayer, 1999, 2000). These studies found that multimedia instruction can improve learning outcomes although multimedia materials can be an ineffective means of instruction for some learners (Mayer, 1997; Mayer & Sims, 1994). According to (Plass, Chun, Mayer, and Leutner (2003): "The effectiveness of learning from multimedia environments depends on differences in the way learners gather and process information" (p. 222).

The way that learners manipulate information depends on the individual differences between them; some of these learning differences are visualizer/verbalizer learning preferences (Jonassen & Grabowski, 1993; Leutner & Plass, 1998) and spatial and verbal ability (Jonassen & Grabowski, 1993; Mayer, 1997; Mayer & Sims, 1994).

Visual ability means the ability to think visually (Crosby et al., 2003). This ability and the degree of using it varies among people (Friedhoff & Benzon, 1989). Several studies found a strong relationship between visual ability and the computer interface or display design (Egan, 1988; Mayer and Sims, 1994). Spatial ability is the ability to judge the relations of objects in space, to judge shapes and sizes, to mentally manipulate objects, to visualize the effects of putting objects together, and to mentally rotate objects around (Sternberg, 1990).

The term "spatial ability" identifies what has also been known as spatial perception, spatial visualization, visual skills, spatial reasoning, mental rotations, and mental rotation (Davey & Holliday, 1992; Dixon, 1995: Stanic & Owen, 1990; Wheatley, 1990). Spatial ability also refers to the ability to rotate or fold objects and to picture the objects that would result from such handling (Mayer & Sims, 1994). This definition is more related to the learning from animation. Sternberg (1990) noted that "this ability is involved in visualization of shapes, rotation of objects, and how pieces of a puzzle would fit together" (p. 93). This spatial ability plays an important role in teaching and learning. It is suggested that higher-spatial-ability learners can more easily create mental representations of the objects (Hays, 1996). They can also keep an image active in working memory in the absence of the visual part and can make connections between this visual and the verbal information.

Large, Beheshti, Breuleux, and Renaud (1996) found that elementary school students with higher spatial ability benefited more from the concurrent presentation of the animation and text than students with lower spatial ability. Other research shows that people who score low in spatial ability have shorter visual memory spans than do people who score high in spatial ability (Carroll, 1993). Mayer and Sims (1994) found that high-spatial-ability students were better than low-spatial-ability students in transferring what they learned when verbal and visual explanations were presented simultaneously.

In summary, learning from words and pictures depends on verbal and spatial abilities, and the focus of this study was on comparing the learning outcomes of students who scored low or high on tests of spatial ability. High spatial ability involves the ability to hold and manipulate mental images with a minimum of mental effort.

According to cognitive theory of multimedia learning, students with high spatial ability are better able to hold visual images in visual working memory, and thus they are more likely to benefit from contiguous presentation of words and pictures. This prediction was tested in two studies in which students with high versus low spatial ability viewed animations with concurrent or successive narration explaining how pumps work or how the human respiratory system works (Mayer & Sims, 1994). Spatial ability was assessed using short paper-and-pencil tests of paper folding and mental rotation. Students with high spatial attention performed better in the transfer test than students with low spatial ability when presenting animation and narration simultaneously rather than successively.

There is a strong connection between spatial ability and the use of computer interfaces. This study tried to reduce split attention by using different visual design (transparent, semi-transparent, and opaque boxes). One of the purposes of this study was to examine the effect of these different visual designs in reducing split attention effect in high-spatial-ability students.

CHAPTER 3
METHODOLOGY

The purpose of this chapter is to describe the design and methodology used to investigate the effects of different cueing strategies that vary only in their opacity on reducing split attention for high- and low-spatial-ability students measured by an achievement test, a performance test, and a mental effort scale. The investigation used an ANCOVA/ANOVA design to answer questions about the effects of various cueing strategies in reducing split attention. Two different experiments were applied using two different topics for the robustness of the results. These topics were 1) how to build a webpage using Dreamweaver and 2) how to create a presentation using PowerPoint.

Description of Participants

Participants in this study were undergraduate students who enrolled in the EME 2040 (Introduction to Educational Technology) course in the 2004 fall semester. This course is offered by the School of Teaching and Learning in the College of Education at the University of Florida to undergraduate students. These students are majoring in education and fields from other colleges at the University of Florida.

The participants were 119 students for Experiment 1 (between the ages of 18 and 23 with 4 males and 115 females) and 122 students for Experiment 2 (between the ages of 18 and 23 with 6 males and 116 females). This course consisted of two components: a lecture and a lab. The lab component of EME 2040 for the fall 2004 semester consisted of eight sections. Of the students in these 8 lab sections, 87% (153) of the students agreed to participate in the study and 12% (21) elected not to participate. Although 153 students agreed to participate in this study, only 119 participated in the first experiment and 122 participated in the second experiment.

Sampling Procedures

Each student in the eight lab sections was randomly assigned to one of the three treatments varying only in the cueing strategy (opaque, semi-transparent or transparent text message box). Students were classified as "low spatial ability" or "high spatial ability" before the treatment using spatial ability measures to examine the effects of different cueing strategies on high- and low-spatial-ability students. Every lab section had some low- and high-spatial-ability students. Students were randomly assigned to one of the three treatments by entering the computer lab and sitting at a computer containing one of the three treatments. In Experiment 1, 19 high-spatial-ability students and 18 low-spatial-ability students served as treatment group1 (opaque cue strategy); 21 high-spatial-ability students and 21 low-spatial-ability students served as treatment group 2 (semi-transparent cue strategy); and 19 high-spatial-ability students and 21 low-spatial-ability students served as treatment group 3 (transparent cue strategy). In Experiment 2, 20 high-spatial-ability students and 19 low-spatial-ability students served as treatment group1 (opaque cue strategy); 21 high-spatial-ability students and 22 low-spatial-ability students served as treatment group 2 (semi-transparent cue strategy); and 19 high-spatial-ability students and 21 low-spatial-ability students served as treatment group 3 (transparent cue strategy).

Research Design

The research study was a pretest-posttest treatment study for two dependent variables (achievement test scores and task performance test scores) and a posttest treatment study for one dependent variable (mental effort scores). Pretest measures were conducted prior to the treatment with posttest measures occurring after the treatment. The pretests were given to every group to ensure there was not a significant difference in the prior knowledge level and performance level in building a webpage using Dreamweaver and creating a presentation using PowerPoint. The pretest measures acted as the covariate for the students' knowledge and performance level. Also, spatial ability measures were applied before the treatment to classify students as having low or high spatial ability. At the conclusion of the treatment, the same achievement and task performance tests were administered again and a mental effort subjective scale to obtain the level of learning difficulty from each treatment. Table 3-1 shows the experimental design for each treatment.

Table 3-1. Experimental Design for Each Treatment

Pretest	Treatment	Posttest
O1O2O3	X	O4O5O6
O1O2O3	X1	O4O5O6
O1O2O3	X2	O4O5O6

Key to Design Items

O1 = Achievement Pretest
O2 = Performance Pretest
O3 = Spatial Ability Measures
O4 = Achievement Posttest
O5 = Performance Posttest
O6 = Mental Effort Subjective Scale
X1 = Treatment 1—Multimedia instruction with opaque cueing strategy

X2 = Treatment 2—Multimedia instruction with semi-transparent cueing strategy
X3 = Treatment 3—Multimedia instruction with transparent cueing strategy

Data Analysis

Quantitative data analysis techniques were used in this study. An ANCOVA/ANOVA was used to provide data to answer questions about the effects of the three treatments varying only in the cueing strategy. An ANCOVA was used to compare the item mean on the dependent variables (achievement posttest scores and performance posttest scores) that were adjusted for the influence of the covariate (achievement pretest scores and performance pretest scores). The covariate (pretest) was used to determine and adjust for initial differences between the groups. This results in a more powerful test of the treatment effect. A post hoc test was conducted to test for differences among the groups.

Materials and Procedure

Materials

Instruments

Seven different instruments were used to examine the effects of different cueing strategies in reducing split attention. These instruments included: two achievement tests, two task performance tests, two spatial ability measures, and a mental effort subjective scale. Because this study involved two different topics and two different experiments, each experiment had an achievement test and a task performance test (one for each topic). The same mental effort subjective scale was used for both experiments. The spatial ability measures were used to classify the students as low- and high-spatial-ability students before the treatment. The following section provides details about the instruments used in this study.

Achievement tests. Two achievement tests were used in this study (one for each topic and each experiment) to measure students' achievement in the content topics covered in this study: (a) building a webpage using Dreamweaver (20 multiple-choice questions) (see Appendix A); and (b) creating a presentation using PowerPoint (18 multiple-choice questions) (see Appendix B). The score range for the Dreamweaver achievement test was 0 to 20, and the score range for the PowerPoint achievement test was 0 to 18.

The investigator attempted to find achievement tests that measured the objective included in the EME 2040 course and were known for their validity and reliability, but was unable to find any. Therefore, an achievement test for each of the Dreamweaver topic and the PowerPoint topic was developed. To identify the validity of these tests, they were given to experts. The experts were graduate students and professors in the educational technology program in the College of Education at the University of Florida. The total number of experts was 10. The investigator included the instructors teaching EME 2040. Also, the investigator met with the instructor who was responsible for teaching the lab component of EME 2040 and went through each test item and matched it with the course objectives. The experts were asked to give their opinion about the formatting of the questions and if they matched the objectives of EME 2040. In a cover letter attached to the tests, the experts were asked to do the following tasks:

- Decide if the test covers all of the objectives.
- Delete any unnecessary item or item that does not measure any of the objectives.
- Add a test item to cover an objective that is not covered.
- Point out any confusing words that may have been used to ask the question.
- Point out questions that considered very easy, very hard, and/or very confusing.

The objective that every test item intended to measure was placed in a column beside the test item (Appendices C and D contain a list of Dreamweaver learning objectives and PowerPoint learning objectives). Ten items from the Dreamweaver test and seven items from the PowerPoint test were modified, based on the experts' review in order to obtain adequate validity for the test items. Some of the original test items were found to have overly long descriptions that might impact students' abilities to understand the questions. Some of the questions used advanced vocabulary in their descriptions, which might be beyond the students' knowledge base in understanding those questions. Some other questions used confusing words or had poor word ordering.

A pilot study to identify the reliability of the test items was conducted in Summer C of 2004. The participants were undergraduate students who enrolled in the EME 2040 course that is offered by the College of Education at the University of Florida. To calculate the average time required to complete each test, students were asked to write their starting and finishing times. The average time that students took to answer the test questions was eight minutes for the Dreamweaver achievement test and seven minutes for the PowerPoint achievement test. Nineteen students (2 males and 17 females) were selected to participate in this pilot study to establish the reliability of the Dreamweaver achievement test, and 16 students (2 males and 14 females) were selected to participate in this pilot study to establish the reliability of the PowerPoint achievement test.

The test items of the pilot study were administered to the students who agreed to participate in the study and who signed consent forms. Nineteen students were asked to recall the knowledge related to building a webpage using Dreamweaver through 26 multiple-choice questions. Sixteen students were asked to recall the knowledge related to creating a presentation using PowerPoint through 23 multiple-choice questions. A reliability measure was run using SPSS (Statistical Package for the Social Sciences). Based on the results of the analysis of the test items, inappropriate items were dropped to increase the reliability to the required standard. Cronbach's Alpha is no less than 0.70. The test items were finalized into a reasonable number of items—20 items for the Dreamweaver test and 16 items for the PowerPoint. The highest reliability value was generated from the statistical measurement (Cronbach's Alpha).

Basically, the value for Cronbach's Alpha should be no less than 0.7 to ensure the reliability of these test items. The 26 Dreamweaver multiple-choice items in this analysis were labeled as Q1 to Q26. The analysis of the value of the Cronbach's Alpha (reliability) increased when certain questions were dropped (see Table 3-2).

Table 3-2. Reliability Value of the Dreamweaver Achievement Test

Dropped variables	Cronbach's Alpha	Number of items
None	.5548	26
Q4	.6599	25
Q1	.6911	24
Q18	.7090	23
Q13	.7229	22
Q16	.7519	21
Q25	.7562	20

Cronbach's Alpha increased to an acceptable value of .7519 when Q16 was dropped. Moreover, when Q25 was dropped along with Q16, the value of Cronbach's Alpha increased to .7562. There was no critical difference in the value of Cronbach's

Alpha between dropping Q16 only and dropping both Q16 and Q25; however, the decision was made to drop both items based on the general preference of having an even number of test questions. Therefore, the final decision was that there would be a total of 20 test items. The reliability of the test items was acceptable, according to the value of Cronbach's Alpha at .7562. The test and the objectives were given to the same 10 experts to confirm that the content validity had not been affected after dropping some of the test items. Their responses confirmed that the test was still valid after dropping the items. The dropped items were highlighted in a different color in order to distinguish them from the other test items, and the experts were informed about the color difference. The 23 PowerPoint multiple-choice items in this analysis were labeled as Q1 to Q23. The analysis of the value of the Cronbach's Alpha (reliability) increased when certain questions were dropped (see Table 3-3).

Table 3-3. Reliability Value of the PowerPoint Achievement Test

Dropped Variables	Cronbach's Alpha	Number of Items
None	.4423	23
Q2	.5471	22
Q18	.6278	21
Q15	.6911	20
Q23	.7123	19
Q5	.7323	18
Q22	.7477	17
Q9	.7621	16

Cronbach's Alpha increased to an acceptable value of .7123 when Q23 was dropped. Moreover, this value increased to .7621 when Q5, Q22, and Q9 were dropped. The reliability of the test items was adequate according to the value of Cronbach's Alpha at .7621. The total number of test items was 16. The test and the objectives were given to the same 10 experts to confirm that the validity had not been affected after dropping some of the test items. The dropped items were highlighted in a different color to distinguish them from the other test items, and the experts were informed about the color difference. Their responses questioned the validity of the test after dropping some of the items. They suggested that the test validity depends on keeping two of the items (Q22 and Q9). If these items were not dropped, the test would be valid. The investigator accepted the suggestion and did not delete Q22 and Q9 because keeping them did not affect the reliability. After returning Q22 and Q9 to the test, the reliability value dropped from .7621 to .7323, which is considered a reasonable reliability value.

After obtaining the reliability for the Dreamweaver achievement test and the PowerPoint achievement test, the tests were administrated again to (5) students who enrolled in EME 2040 for the 2004 Summer C semester. The purpose of this pilot study was to obtain the average time required to answer the test items, which was 6 minutes for the Dreamweaver test and 5 minutes for the PowerPoint test.

Task performance tests. The investigator attempted to find task performance tests that measured the objectives included in the EME 2040 course with establishing reliability and validity, but was unable to find any. Therefore, the investigator used the task performance tests and evaluation rubrics that were used to evaluate students' performance in (a) building a webpage using Dreamweaver and (b) creating a presentation using PowerPoint (see Appendixes E, F, G, and H) in the EME 2040 course. The principal investigator made changes to these task performance tests and evaluation rubrics by adding more tasks to the task performance tests that covered objectives that were not covered by the original tests. She also rephrased some of the tasks included in the task performance test. Each task performance test contained instructions that asked students to build a webpage or create a PowerPoint presentation using the actual software. Evaluation rubrics were used to evaluate the final products. The score range of the Dreamweaver task performance test was 0 to 17, and the score range of the PowerPoint task performance test was 0 to 12.

Experts were given the task performance tests and rubrics to identify their validity. Those experts were graduate students and professors in the educational technology program in the College of Education at the University of Florida. The investigator included the instructors who were teaching EME 2040 to get their opinion about the formatting of the tasks, and whether or not they matched the objectives of the EME 2040 course. Also, the investigator met with the instructor responsible for teaching the lab component of EME 2040, examined the test items, and matched them with the objectives. The number of experts was 10. The experts were asked about the following in a cover letter attached to the tests and the rubrics:

- Decide if the test covers all of the objectives.
- Delete any unnecessary item or item that does not measure any of the objectives.
- Add a test item to cover an objective that is not covered.
- Point out any confusing words that may have been used to ask the question.
- Point out questions that considered very easy, very hard, and/or very confusing.

The objective that every task intended to measure was placed in a column beside the test item. Appendixes C and D contain a list of the Dreamweaver learning objectives and PowerPoint learning objectives. Some of the test tasks and evaluation rubrics criteria were modified based on the experts' review in order to obtain adequate validity for the tests' tasks and the rubrics' items.

A pilot study to identify the inter-rater reliability of the evaluation rubrics was conducted in Summer C of 2004. The participants were undergraduate students who enrolled in the EME 2040 course that was offered by the College of Education, University of Florida in Summer C of 2004. Five students participated in this study. After learning how to build a webpage using Dreamweaver and how to create a presentation using PowerPoint, every student was asked to build a webpage using Dreamweaver and create a PowerPoint presentation. This pilot study was conducted during a period of two weeks: the first week for the Dreamweaver topic and the second week for the PowerPoint topic. The investigator collected the final products (webpages and PowerPoint presentations) by saving them to a USB drive. The investigator then copied them on CDs and gave them to seven experts (graduate students and professors from the educational technology program who had taught PowerPoint and Dreamweaver for many years as well as the instructors of EME 2040). These seven experts evaluated these products using the evaluation rubrics attached. The raters (experts) rated students' products in a 3-point Likert-type scale with raters being asked to rate every product by checking one of the three choices: unsatisfactory (corresponding to score 0); needs improvement (corresponding to score .5); and excellent (corresponding to score 1). Evaluation instructions were attached in a cover letter.

After receiving the evaluation rubrics from the raters, an inter-rater reliability analysis was conducted using SPSS. The final inter-rater reliability, Cronbach's Alpha value for the Dreamweaver evaluation rubric, was .8215, which was considered a good reliability value. The reliability for the PowerPoint evaluation rubric was very low. The investigator detected that the raters were confused in rating some tasks (from the raters' comments). For example, when inserting a picture into the presentation, some students used a background picture for the presentation but did not use any pictures as a part of the presentation content. The raters were confused in rating this task when the students used a background image but did not insert an image. The investigator rephrased many of the evaluation rubric items according to the raters' comments. The investigator then reapplied the PowerPoint task performance test to obtain the evaluation rubric reliability again. Five students who enrolled in EME 2040 were selected for this pilot study. The final products were given to seven raters. An inter-rater reliability analysis was conducted using SPSS. The final inter-rater reliability Cronbach's Alpha value for the PowerPoint evaluation rubric was .7911. This value is considered a good reliability value.

Mental effort scale. A subjective mental effort scale was used to determine the learning difficulty level of each treatment. This mental effort scale was used successfully in many studies (Kalyuga et. al., 1999; Paas & van Merriënboer, 1992), and it was modified from the original version by Paas and van Merriënboer (1992). After each treatment, students were asked to rate the subjective mental load associated with learning the instructional materials. Ratings were collected on a 9-point Likert-type scale with participants being asked to estimate the amount of mental effort they spent while learning the instructional materials. They had to check one of the nine choices: from very very low mental effort (corresponding to the score 1) to very very high mental effort (corresponding to the score 9). The reliability of the scale was estimated with Cronbach's Alpha. A coefficient of reliability of .85 was obtained (Gimino, 2001). Results obtained from this rating scale were used as an indicator of cognitive load (the higher the score, the higher the estimated mental load) (see Appendix J).

Spatial ability measures. Before the treatment, participants took a battery of two spatial ability measures, the Card Rotations Test from the Kit of Factor-Referenced Cognitive Tests and the Paper-Folding Test from the Kit of Factor-Referenced Cognitive Test published by the Educational Testing Service (Ekstrom, French, Harman, & Dermen 1976). The purpose of these measures was to classify students as having high or low spatial ability.

The paper-folding test consisted of two parts with each part consisting of 10 items, which are similar to the example shown in the top portion of Appendix I. Each item visually described a sheet of paper that was folded one or more times with a hole punched through the folded paper and presented five alternative answers for how the sheet would look when it was unfolded. The instructions called for selecting the correct alternative for each problem, and 1 point was given for each correct answer. Each part had a time limit of 3 minutes. The students were asked not to turn the page and continue to the next page unless they were instructed to do so. A score was determined by subtracting a portion of the wrong answers (1/5) from the correct answers ($x - y/5$), where x referred to the correct answers and y referred to the wrong answers. The maximum score for each part was 10, and was 20 for the two parts combined. The card rotation test consisted of 10 rows of nonsense shapes; each row contained a target shape on the left-hand side and eight rotated shapes on the right-hand side, as shown in the bottom portion of Appendix I. The instructions called for marking each rotated shape as "same" if that shape was a rotated version of the target and "different" if it was not. A score was determined by subtracting the number of incorrect answers from the total number of correct answers (x-y), where x referred to the correct answers and y referred to the wrong answers. Each part had a time limit of 3 minutes. The students were asked not to turn the page and continue to the other page unless they were instructed to do so. The maximum score was 80 for each part and 160 for both parts combined. The mental rotation and paper-folding tests are a composite. The spatial ability score was determined by adding the scores on the two tests. The two tests have a very high correlation. The investigator used median split to classify students to high- and low-spatial-ability students. Students scoring less than 130 were classified as "low spatial ability" and students scoring 130 or above were classified as "high spatial ability". The internal reliability of the paper-folding test was 0.84, and the reliability of the mental rotation test was .80.

The card rotation test and paper-folding tests were chosen for this study because

1. They measure an important component of spatial ability that is related to the technique of processing visual materials required in this study.
2. They are speed tests that measure aspects of cognitive load relevant in this study.
3. They were used successfully in previous studies (Mayer, 2001; Mayer & Sims, 1994).
4. They are simple and quick tests.
5. The card rotation test and paper-folding test depend on speedy performance in the processing of a meaningful pictorial representation, a skill that is consistent with this study's interests in cognitive load in multimedia learning.

The investigator contacted the Educational Testing Service (ETS) to obtain a copy of the spatial ability measures. The investigator was instructed to buy a license, considering the number of the students who were going to use these measures. The investigator bought 150 licenses for each spatial ability measure and was instructed by ETS not to include a copy of the measures in the dissertation; therefore, this dissertation includes only a sample from the actual measures (see Appendix J).

Multimedia instruction

The multimedia instructional program is a computerized software program that uses narrated animation with text cues explaining either how to build a webpage using Dreamweaver (12 minutes) or how to create a presentation using PowerPoint (10 minutes). The narration was spoken by a native English speaker (female voice). The narrator had a great deal of experience with both PowerPoint and Dreamweaver and had taught both applications for several years. The animations were animated screen captures. The animations and narrations were the same across the three treatments with the only difference among the three treatments being the text cues. The text cues were provided to present critical information and to guide students to reduce visual search, which decreases the split attention effect. These cues varied in their opacity. The first treatment received training using an opaque background for the text cue message box. The second treatment received training using a semi-transparent background for the text cue message box. The third treatment received training using a transparent background for the text cue message box.

Before conducting the actual treatment, a pilot study was conducted to examine the three different treatments for every topic. The purpose of this pilot study was to determine if the students would encounter any problems while learning from any of the three treatments. Three students were voluntarily selected for this pilot study from the EME 2040 course, Summer C 2004. Students stated that the multimedia instruction was clear and they found it very interesting. One of the students indicated that it would be better if he could control the multimedia instruction (rewind, forward, stop, etc.). Consistent with the student's suggestion, a controller was added to all multimedia instruction.

Procedures

The experiment was applied in the same manner twice (same design, participants, materials, and procedures) using two different topics to determine the robustness of the results. Two topics from the lab section (how to build a webpage using Dreamweaver and how to create a presentation using PowerPoint) were selected for the purposes of this study. The topics from the lab section usually were taught by giving the students a practice printed tutorial to learn about a piece of software with the guidance of the instructor.

Two experiments were conducted with each consisting of two sessions. An additional session was conducted before the two experiments to apply the spatial ability measures in order to classify the students as having high spatial ability and low spatial ability. The location of the study was the CIRCA computer lab, room G512, located in the College of Education, University of Florida, which is the same lab for teaching the EME 2040 course.

Experiment 1

The topic of this experiment was how to build a webpage using Dreamweaver. In the first session, students took a multiple-choice achievement test about their knowledge of Dreamweaver and a task performance test (pretests). Students were given the multiple-choice achievement tests first. When they finished the achievement tests, they were given a task performance test that asked them to build a webpage using Dreamweaver following the tasks in the Dreamweaver task performance test.

In the second session, students were randomly assigned to one of the three treatment groups that varied only in the cueing strategy. Every student received multimedia training for about 12 minutes that showed him how to build a webpage using Dreamweaver. After completing the training, the students took an achievement test for 7 minutes, were asked to build a webpage using Dreamweaver (the time allowed for this task was the time that remained between finishing the achievement test and the end of the class period), and answered the questions of the subjective mental effort scale. G5 Macintosh computers with headphones were used in this study.

Experiment 2

During the first session, students took a multiple-choice achievement test about their knowledge of PowerPoint and a performance test, which asked them to build a presentation using the actual PowerPoint software. Students were asked to answer the PowerPoint multiple-choice achievement test questions and create a presentation using PowerPoint following the tasks in the Dreamweaver performance test.

In the second session, students were randomly assigned to one of the three treatment groups that varied in cueing strategy. Every student received computer-training software that showed him how to build a presentation using PowerPoint for about 10 minutes. After completing the training session, students took an achievement test for 6 minutes, were asked to create a presentation using PowerPoint (the time allowed for this task was the time that remained between finishing the achievement test and the end of the class period), and answered the questions of the subjective mental effort scale. G5 Macintosh computers with headphones were used in this study.

In both experiments students were give written and verbal instructions about what they should do. Because it was very difficult to collect all the final products (the webpages and the PowerPoint presentations), the principal investigator asked the instructor of EME 2040 to teach the students how to use Fetch (an FTP software program that allows a transfer of files from a computer to a server). The instructor agreed to do so, and the students became familiar with the file-transferring process using Fetch.

The students were given written and oral instructions on how to upload the final products using Fetch to the investigator's account. The host name, user ID, and password needed for this process were given to the students in the written instructions. To make the process easier for the students, the principal investigator created folders on the server for each section and named these folders using the day and time of the meeting. Inside this folder, other folders were created using students' first and last names. Every student was asked to upload the final product to the folder that had his name on it. These oral and written instructions were given to the students twice.

Dependent and Independent Variables

The following dependent variables were used in the study:

Pretest score: Knowledge of Dreamweaver and PowerPoint. This variable was defined by the students' score on the pencil-and-paper instrument, which was designed to determine the participants' knowledge of Dreamweaver and PowerPoint before they received the treatment. The score range was 0 to 20 for the Dreamweaver achievement test and 0 to 18 for the PowerPoint achievement test.

Pretest score: Performance in building a webpage using Dreamweaver and creating a presentation using PowerPoint. This variable was defined by the students' scores on the evaluation rubric, which was designed to determine the participants' performance level in building a webpage using Dreamweaver and creating a presentation using PowerPoint before receiving the treatment. The score range was 0 to 17 for the Dreamweaver task performance test and 0 to 12 for the PowerPoint task performance test.

Posttest score: Knowledge of Dreamweaver and PowerPoint. This variable was defined by the students' scores on the pencil-and-paper instrument, which was designed to determine the participants' knowledge of Dreamweaver and PowerPoint after receiving the treatment. The score range was 0 to 20 for the Dreamweaver achievement test and 0 to 18 for the PowerPoint achievement test.

Posttest score: Performance in building a webpage using Dreamweaver and creating a presentation using PowerPoint. This variable was defined by the students' scores on the evaluation rubric, which was designed to determine the participants' performance level in building a webpage using Dreamweaver and creating a PowerPoint presentation after receiving the treatment. The score range was 0 to 17 for the Dreamweaver task performance test and 0 to 12 for the PowerPoint task performance test.

Mental effort score. The students' scores on the mental effort subjective scale defined this variable. The scores obtained on this instrument determined the level of difficulty of learning from the three different treatments. The score range was 1 to 9.

The following independent variables were used in the study:

Multimedia instruction. Three different versions of the instruction varied only in the use of different visual cues (opaque, semi-transparent, transparent).

Spatial ability score. This variable was designed by using the students' scores in the two spatial ability measures. Students were classified into groups of high-spatial ability and low-spatial ability students, determined by the scores of the spatial ability measures, before receiving treatment.

Hypotheses

This study involved the following hypotheses:

1. There is no significant difference among all subjects in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect measured by an achievement test (Experiments 1 and 2).
2. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among low-spatial-ability students measured by an achievement test (Experiments 1 and 2).
3. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among high-spatial-ability students measured by an achievement test (Experiments 1 and 2).
4. There is no significant difference among all subjects in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect measured by a task performance test (Experiments 1 and 2).
5. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among low-spatial-ability students measured by a task performance test (Experiments 1 and 2).
6. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among high-spatial-ability students measured by a task performance test (Experiments 1 and 2).
7. There is no significant difference among all subjects in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect measured by a mental effort scale (Experiments 1 and 2).
8. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among low-spatial-ability students measured by a mental effort scale (Experiments 1 and 2).

9. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among high-spatial-ability students measured by a mental effort scale (Experiments 1 and 2)

CHAPTER 4
RESULTS

This study was designed to investigate the effectiveness of different cueing strategies in multimedia instruction on reducing split attention in terms of the students' improvement in their test scores and the amount of mental effort they spent in learning the instructional materials. The research questions described in Chapter 3 concentrated on whether or not different cueing strategies that vary in their opacity can affect reducing the split attention effect and, accordingly, affect learning from multimedia materials.

This chapter presents the descriptive statistics of the participants and the results of the ANCOVA and ANOVA analyses, and it concludes with a summary of major findings.

Descriptive Statistics of the Sample

Participants for this study were undergraduate students who enrolled in the EME 2040 (Introduction to Educational Technology) course. This sample was chosen by the investigator as a representative sample of undergraduate students at the University of Florida. The sample consisted of 119 students for the Dreamweaver topic (Experiment 1) and 122 students for the PowerPoint topic (Experiment 2). In Experiment 1, 59 students were classified as being "high" in spatial abilities, and 60 were classified as being "low" in spatial abilities. In Experiment 2, 60 students were classified as being "high" in spatial abilities, and 62 were classified as being "low" in spatial abilities. This classification was based on the spatial ability measures.

Group Formation

The students in every section from the eight lab sections were randomly assigned to one of the three multimedia treatments that vary only on the opacity of the text message box (opaque, semi-transparent, and transparent).

Treatment

The achievement pretests/posttests and mental effort scale in this study were paper and pencil tests. The task performance pretests/posttests asked the students to utilize the actual software using the computer to create a webpage using Dreamweaver or a presentation using PowerPoint. With the help of the lab instructor, the investigator applied all the treatments using multimedia instruction (varying only on the cueing strategy). The selected topics of instruction were how to build a webpage using Dreamweaver (Experiment 1) and how to create a presentation using PowerPoint (Experiment 2). Two experiments were conducted for the robustness of the results.

Hypothesis Testing

A 3 (treatments) x 2 (high/low spatial ability) ANCOVA (for the achievement dependent variable in Experiment 1) and (achievement and performance dependent variables in Experiment 2) and an ANOVA (for the mental effort scale dependent variable in both experiments and for the performance dependent variable in Experiment 1) were employed to determine the effect of the treatments and students' spatial ability on reducing the split attention effect.

It was concluded from this correlation analysis that there was a low but significant correlation between the achievement pretest and the achievement posttest for both experiments and also between the performance pretest and the performance posttest for Experiment 2. However, no significant correlation existed between the task performance pretest and the task performance posttest in Experiment 1. Accordingly, an analysis of covariance (ANCOVA) was used to compare the mean scores on the dependent variables (posttests) – except for the mental effort scale – because it was only a posttest and the task performance test in Experiment 1 – an analysis of variance (ANOVA) was used. The study used an experimental design for the groups because each student was randomly assigned to one of the three treatments. The experimental design used in this study was a pretest-posttest experimental design for two dependent variables (achievement test and task performance test) and a posttest experimental design for one dependent variable (mental effort scale). Tables 4-1 and 4-2 show the descriptive statistics of the means and standard deviation for pretest and posttest scores of the three treatments for Experiment 1 and Experiment 2, respectively.

Hypothesis #1. There is no significant difference among all subjects in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect measured by an achievement test (Experiments 1 and 2).

Table 4-1. Descriptive Statistics of the Means and Standard Deviation for the Pretest and the Posttest Scores for the Three Treatments – Experiment 1

Treatment		Mental Effort	Pretest Achievement	Posttest Achievement	Pretest Performance	Posttest Performance
Opaque	M	5.5135	3.6216	16.8378	.6486	14.7297
	N	37	37	37	37	37
	SD	1.44571	1.93436	1.57257	1.13569	1.69392
Semi	M	7.2619	3.5238	17.4762	.8095	16.0000
	N	42	42	42	42	42
	SD	1.19060	2.08640	1.77019	1.17366	1.03594
Transparent	Mean	5.0000	3.3500	16.7500	.8500	13.7000
	N	40	40	40	40	40
	SD	1.66410	1.86121	1.31559	.89299	1.62038
Total	Mean	5.9580	3.4958	17.0336	.7731	14.8319
	N	119	119	119	119	119
	SD	1.73886	1.95229	1.58880	1.06911	1.74336

Table 4-2. Descriptive Statistics of the Means and Standard Deviation for the Pretest and the Posttest Scores for the Three Treatments – Experiment 2

Treatment		Mental Effort	Pretest Achievement	Posttest Achievement	Pretest Performance	Posttest Performance
Opaque	Mean	6.3077	4.3077	14.1538	3.8462	9.6923
	N	39	39	39	39	39
	SD	1.34074	1.70377	2.50829	2.03313	1.43552
Semi	Mean	7.4884	4.4651	14.7209	3.3721	10.8837
	N	43	43	43	43	43
	SD	1.07730	1.56371	2.31276	1.91514	1.23846
Transparent	Mean	5.7500	3.9250	13.9750	2.8500	9.5000
	N	40	40	40	40	40
	SD	1.59727	1.68534	1.91469	2.05751	1.50214
Total	Mean	6.5410	4.2377	14.2951	3.3525	10.0492
	N	122	122	122	122	122
	SD	1.52742	1.65171	2.26248	2.02432	1.51495

To test this hypothesis an ANCOVA was used; Table 4-3 shows the results of the ANCOVA analysis for Experiment 1.

Table 4-3. ANCOVA for the Achievement Posttest (Among All Subjects) – Experiment 1

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Model	30.961	6	5.160	2.165	.052
Achievement Pretest	13,124	1	13.124	5.507*	.021
Treatment	12.236	2	6.118	2.567	.081
Spatial Ability	1.685	1	1.685	.707	.402
Treatment* Spatial Ability	2.014	2	1.007	.423	.656
Error	266.905	112	2.383		

* Significant at the 0.05 level

The 3 x 2 ANCOVA indicated no significant main effects for spatial ability [F (1, 112) = .707, p = .402], no significant main effects for the treatment [F (2, 112) = 2.567, p = .081], and no significant interaction between treatment and spatial ability (p = .656), which means that spatial abilities did not influence achievement by treatment.

Table 4-4 shows that the same results were obtained from Experiment 2. These results were consistent with the results obtained from Experiment 1.

Table 4-4. ANCOVA for the Achievement Posttest (Among All Subjects) – Experiment 2

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Model	58.361	6	9.727	1.994	.072
Achievement Pretest	14.880	1	14.880	3.050	.083
Treatment	9.809	2	4.905	1.005	.369
Spatial Ability	12.068	1	12.068	2.474	.119
Treatment* Spatial Ability	18.408	2	9.204	1.887	.156
Error	561.016	115	4.878		

* Significant at the 0.05 level

Hypothesis #2. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among low-spatial-ability students measured by an achievement test (Experiments 1 and 2).

Hypothesis #3. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among high-spatial-ability students measured by an achievement test (Experiments 1 and 2).

To test Hypotheses #2 and #3, separate analyses were conducted within each spatial level group for treatment comparisons. From Experiment 1, it was found there was no significant difference in the achievement test scores among low-spatial-ability students exposed to the three treatments [F (2, 56) = .729, p = .487] (see Table 4-5). Experiment 2 revealed the same results: there was no significant difference among the low-spatial-ability groups [F (2, 58) = 1.453, p = .242] (Table 4-6). See Table 4-5 for the results of Experiment 1 and Table 4-6 for the results of Experiment 2.

Table 4-5. ANCOVA for the Achievement Posttest (Among Low-Spatial-Ability Students) – Experiment 1

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Model	7.010	3	2.337	.927	.434
Achievement Pretest	4.565	1	4.565	1.811	.184
Treatment	3.676	2	1.838	.729	.487
Error	141.173	56	2.521		

* Significant at the 0.05 level

Table 4-6. ANCOVA for the Achievement Posttest (Among Low-Spatial-Ability Students) – Experiment 2

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Model	18.162	3	6.054	1.010	.395
Achievement Pretest	1.365	1	1.365	.228	.635
Treatment	17.426	2	8.713	1.453	.242
Error	347.774	58	5.996		

* Significant at the 0.05 level

The same results were found among high-spatial-ability students. From Experiment 1, it was found that there was no significant difference in the achievement test scores among high-spatial-ability students exposed to the three treatments [F (2, 55) = 2.158, p = .125] (Table 4-7). Experiment 2 revealed the same results; there was no significant difference among the high-spatial-ability groups [F (2, 56) = 1.097, p = .341] (Table 4-8). See Table 4-7 for the results of Experiment 1 and Table 4-8 for the results of Experiment 2.

Table 4-7. ANCOVA for the Achievement Posttest (Among High-Spatial-Ability Students) – Experiment 1

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Model	21.710	3	7.237	3.178*	.031
Achievement Pretest	9.051	1	9.051	3.975	.051
Treatment	9.829	2	4.914	2.158	.125
Error	125.239	55	2.277		

* Significant at the 0.05 level

Table 4-8. ANCOVA for the Achievement Posttest (Among High-Spatial-Ability Students) – Experiment 2

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Model	30.289	3	10.096	2.697	.054
Achievement Pretest	17.113	1	17.113	4.571*	.037
Treatment	8.214	2	4.107	1.097	.341
Error	209.644	56	3.744		

* Significant at the 0.05 level

Hypothesis #4. There is no significant difference among all subjects in using fully opaque, semi-transparent and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect measured by a task performance test (Experiments 1 and 2).

To test this hypothesis, an ANOVA was conducted instead of ANCOVA because there was no correlation between the task performance pretest and the task performance posttest. Table 4-9 shows the results of the ANOVA analysis for Experiment 1.

The 3 x 2 ANOVA indicated significant main effects for the treatment [F (2, 112) = 26.724, p = .000], significant main effect for spatial ability [F (1, 112 = 6.972, p = .004), and no significant interaction between treatment and spatial ability (p = .157).

Table 4-9. ANOVA for the Task Performance Posttest (Among All Subjects) – Experiment 1

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Treatment	108.591	2	54.295	26.724*	.000
Spatial Ability	14.165	1	14.165	6.972*	.004
Treatment* Spatial Ability	7.645	2	3.823	1.881	.157
Error	261.294	112	2.032		

* Significant at the .05 level

Because the treatment main effect was significant, supplemental post hoc tests were conducted. The opaque group scored significantly higher than the transparent group (p = .009); the semi-transparent group scored significantly higher than each of the transparent groups (p =.000) and the opaque group (p = .000). Table 4-10 shows that the same results were reached from Experiment 2.

Table 4-10. ANCOVA for the Task Performance Posttest (Among All Subjects) – Experiment 2

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Model	58.654	5	11.731	6.212*	.000
Task Performance Pretest	10.652	1	10.652	5.641*	.019
Treatment	42.686	2	21.343	11.302*	.000
Spatial Ability	1.287	1	1.287	.682	.411
Treatment* Spatial Ability	.675	1	.675	.357	.551
Error	219.051	116	1.888		

* Significant at the .05 level

The 3 x 2 ANCOVA indicated no significant main effects for spatial ability [F (1, 116) = .682, p = .411], significant main effects for the treatment [F (2, 116) = 11.302, p = .000], and no significant interaction between treatment and spatial ability (p = .551).

Because the treatment main effect was significant, supplemental post hoc tests were conducted. There was no significant difference between the opaque group and the transparent group (p = 1.000); the semi-transparent group scored significantly higher than each of the transparent groups (p = .000) and the opaque group (p = .000).

Hypothesis #5. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among low-spatial-ability students measured by a task performance test (Experiments 1 and 2).

Hypothesis #6. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among high-spatial-ability students measured by a task performance test (Experiments 1 and 2).

Separate analyses were conducted within each spatial level group for treatment comparisons. From Experiment 1, there was significant difference in the performance test scores among low-spatial-ability students exposed to the three treatments [F (2, 56) = 7.543, p = .001] (see Table 4-11). Because the treatment main effect was significant, supplemental post hoc tests were conducted. There was no significant difference between each of the opaque groups and the transparent group (p = 1.000); the semi-transparent group scored significantly higher than each of the transparent groups (p = .002) and the opaque group (p = .015).

Table 4-11. ANOVA for the Task Performance Posttest (Among Low-Spatial-Ability Students) – Experiment 1

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Treatment	45.168	2	22.584	7.543*	.001
Error	167.659	56	2.994		

* Significant at the 0.05 level

Experiment 2 revealed the same results; there was significant difference among the low-spatial-ability groups [F (2, 58) = 5.654, p = .006] (see Table 4-12). Because the treatment main effect was significant, supplemental post hoc tests were conducted. There was no significant difference between the opaque group and the transparent group (p = 1.000); the semi-transparent group scored significantly higher than each of the transparent groups (p = .015) and the opaque group (p = .018). See Table 4-11 for the results of Experiment 1 and Table 4-12 for the results of Experiment 2.

Table 4-12. ANCOVA for the Task Performance Posttest (Among Low-Spatial-Ability Students) – Experiment 2

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Model	34.984	3	11.661	6.208*	.001
Task Performance Pretest	7.223	1	7.223	3.845	.055
Treatment	21.241	2	10.621	5.645*	.006
Error	108.952	58	1.878		

* Significant at the 0.05 level

The same results were found among high-spatial-ability students. From Experiment 1, there was significant difference in the performance test scores among high-spatial-ability students exposed to the three treatments [F (2, 55) = 31.836, p = .000] (Table 4-13). A supplemental post hoc test revealed that among the high-spatial-ability students the opaque (p = .000) and semi-transparent (p = .000) groups were better than the transparent group, and the high-spatial-ability students in the semi-transparent group scored significantly higher than the opaque group (p = .014). Experiment 2 revealed the same results; there was a significant difference among the high-spatial-ability groups [F (2, 56) = 5.455, p = .007] (see Table 4-14). The semi-transparent group was better than the transparent group (p = .016) and the opaque group (p = .023), and there was no significant difference between the opaque group and the transparent group (p = 1.000). See Table 4-13 for the results of Experiment 1 and Table 4-14 for the results of Experiment 2.

Table 4-13. ANOVA for the Task Performance Posttest (Among High-Spatial-Ability Students) – Experiment 1

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Treatment	68.034	2	34.017	31.836*	.000
Error	58.768	55	1.096		

* Significant at the 0.05 level

Table 4-14. ANCOVA for the Task Performance Posttest (Among High-Spatial-Ability Students) – Experiment 2

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Model	22.837	3	7.612	3.872*	.014
Task Performance Pretest	3.335	1	3.335	1.696	.198
Treatment	21.449	2	10.725	5.455*	.007
Error	110.096	56	1.966		

* Significant at the 0.05 level

Hypothesis #7. There is no significant difference among all subjects in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect measured by a mental effort scale (Experiments 1 and 2).

To test this hypothesis, an ANOVA was conducted; Table 4-15 shows the results of the ANOVA analysis.

Table 4-15. ANOVA for the Mental Effort Posttest (Among All Subjects) – Experiment 1

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Model	125.366	5	25.073	12.243*	.000
Treatment	115.589	2	57.795	28.220*	.000
Spatial Ability	5.898	1	5.898	2.880	.092
Treatment*Spatial Ability	4.474	2	2.237	1.092	.339
Error	231.424	113	2.048		

* Significant at the 0.05 level

The 3 x 2 ANOVA indicated no significant main effects for spatial ability [F (1, 113) = 2.880, p = .092], significant main effects for the treatment [F (2, 113) = 28.220, p = .000], and no significant interaction between treatment and spatial ability (p = .339).

Because the treatment main effect was significant, supplemental post hoc tests were conducted. The semi-transparent group scored significantly higher than both the transparent group (p =.000) and the opaque group (p = .000). There was no significant difference between the opaque group and transparent group (p = .392). Table 4-16 shows that the same results were reached from Experiment 2

Table 4-16. ANOVA for the Mental Effort Posttest (Among All Subjects) – Experiment 2

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Model	74.058	5	14.812	8.251*	.000
Treatment	65.654	2	32.827	18.287*	.000
Spatial Ability	.808	1	7.808	4.349*	.039
Treatment*Spatial Ability	.590	2	.290	.164	.849
Error	208.237	116	1.795		

* Significant at the 0.05 level

The 3 x 2 ANOVA indicated significant main effects for spatial ability [F (1, 116) = 4.349, p = .039], significant main effects for the treatment [F (2, 116) = 18.287, p = .000], and no significant interaction between treatment and spatial ability (p = .849).

Because the treatment main effect was significant, supplemental post hoc tests were conducted. The semi-transparent group scored significantly higher than both the transparent group (p = .000) and the opaque group (p = .000). There was no significant difference between the opaque and transparent groups (p = .230).

Hypothesis #8. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among low-spatial-ability students measured by a mental effort scale (Experiments 1 and 2).

Hypothesis #9. There is no significant difference in using fully opaque, semi-transparent, and fully transparent backgrounds for the text message boxes in multimedia instruction on reducing the split attention effect among high-spatial-ability students measured by a mental effort scale (Experiments 1 and 2).

To test hypothesis #8 and hypothesis #9, separate analyses were conducted within each spatial level group for treatment comparisons. Experiment 1 revealed that there was a significant difference in the mental effort scores among low-spatial-ability students exposed to the three treatments [F (2, 56) = 12.441, p =.000] (see Table 4-17). A supplemental post hoc test revealed that among the low-spatial-ability students, the semi-transparent group scored significantly better than the opaque group (p = .015) and transparent group (p = .000). There was no significant difference between the transparent and the opaque groups (p = .164). Experiment 2 revealed the same results; there was significant difference in the mental effort scores among low-spatial-ability students exposed to the three treatments [F (2, 59) = 8.846, p = .000] (see Table 4-18). A supplemental post hoc test revealed that among the low-spatial-ability students, the semi-transparent group scored significantly better than the opaque group (p = .011) and the transparent group (p = .001). There was no significant difference between the transparent and the opaque groups (p = 1.000). See Table 4-17 for the results of Experiment 1 and Table 4-18 for the results of Experiment 2.

Table 4-17. ANOVA for the Mental Effort Posttest (Among Low-Spatial-Ability Students) – Experiment 1

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Model	55.049	2	27.525	12.441*	.000
Treatment	55.049	2	27.525	12.441*	.000
Error	123.900	56	2.212		

* Significant at the 0.05 level

Table 4-18. ANOVA for the Mental Effort Posttest (Among Low-Spatial-Ability Students) – Experiment 2

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Treatment	43.320	2	17.160	8.846*	.000
Error	114.454	59	1.940		

* Significant at the 0.05 level

Separate analyses were conducted within the high-spatial-ability group for treatment comparisons. Experiment 1 revealed that there was a significant difference in the mental effort scores among high-spatial-ability students exposed to the three treatments [F (2, 57) = 17.019, p = .000] (see Table 4-19). A supplemental post hoc test revealed that among the high-spatial ability students, the semi-transparent group was better than the transparent group (p = .000) and the opaque group (p = .000). There is no significant difference between the opaque and transparent group (p = 1.000). Experiment 2 revealed the same results: a significant difference among the high-spatial-ability groups [F (2, 57) = 9.669, p = .000] (see Table 4-20). The semi-transparent group was better than the transparent group (p = .000), and the opaque group (p = .031). There is no significant difference between the opaque and transparent group (p = .278). See Table 4-19 for the results of Experiment 1 and Table 4-20 for the results of Experiment 2.

Table 4-19. ANOVA for the Mental Effort Posttest (Among High-Spatial-Ability Students) – Experiment 1

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Treatment	64.210	2	32.105	17.09*	.000
Error	107.524	57	1.886		

* Significant at the 0.05 level

Table 4-20. ANOVA for the Mental Effort Posttest (Among High-Spatial-Ability Students) – Experiment 2

Source	SS	DF	Mean Square	F Value	Sig. (p-value)
Treatment	31.817	2	15.908	9.669*	.000
Error	125.600	57	1.645		

* Significant at the 0.05 level

Summary

This study examined the effects of different cueing strategies in multimedia instruction on reducing split attention in terms of the students' improvement in their test scores and the amount of mental effort spent in learning the instructional materials.

Quantitative data were used to determine if there were significant differences among the three treatment groups, among low-spatial-ability students, and among high-spatial-ability students in posttest measures of achievement, performance and mental effort.

The results of the null hypotheses are presented below:

1. There was no significant difference among the three treatment groups in the achievement posttest scores (Experiment 1 and Experiment 2). The null hypothesis could not be rejected.

2. There was no significant difference among low-spatial-ability students in the achievement posttest scores (Experiment 1 and Experiment 2). The null hypothesis could not be rejected.

3. There was no significant difference among high-spatial-ability students in the achievement posttest scores (Experiment 1 and Experiment 2). The null hypothesis could not be rejected.

4. There was a significant difference among the three treatment groups in the performance posttest scores (Experiment 1 and Experiment 2). The null hypothesis was rejected.
   The semi-transparent group outperformed each of the opaque groups and the transparent group (Experiment 1 and Experiment 2).
   The opaque group outperformed the transparent group (Experiment 1). There was no significant difference between the opaque group and transparent group (Experiment 2).

5. There was significant difference among low-spatial-ability groups in the performance posttest scores (Experiment 1 and Experiment 2). The null hypothesis was rejected.

6. There was significant difference among high-spatial-ability groups in the performance posttest scores (Experiment 1 and Experiment 2). The null hypothesis was rejected.
   The semi-transparent group outperformed each of the opaque groups and the transparent group (Experiment 1 and Experiment 2).
   The opaque group outperformed the transparent group (Experiment 1). There was no significant difference between the opaque group and transparent group (Experiment 2).

7. There was a significant difference among the three treatment groups in the mental effort scores (Experiment 1 and Experiment 2). The null hypothesis was rejected. The semi-transparent group outperformed each of the opaque groups and the transparent group.

8. There was a significant difference among low-spatial-ability groups in the mental effort scores (Experiment 1 and Experiment 2). The null hypothesis was rejected. The semi-transparent group outperformed each of the opaque groups and the transparent group.

9. There was a significant difference among high-spatial-ability groups in the mental effort scores (Experiment 1 and Experiment 2). The null hypothesis was rejected. The semi-transparent group outperformed each of the opaque groups and the transparent group.

CHAPTER 5
DISCUSSION

This study investigated how different cueing strategies in multimedia instruction impacted split attention and, therefore, learning from multimedia instruction for high and low spatial abilities. The results of the experiments showed that using different cueing strategies in multimedia instruction revealed different results in guiding students' visual attention and in eliminating unnecessary visual search.

Among the three treatments, students who received opaque cueing treatment did not score significantly higher in the achievement test than students who received semi-transparent cueing or transparent cueing treatment for both Experiment 1 and Experiment 2. Different results were revealed from the performance test scores. Students who were exposed to the semi-transparent cueing treatment performed significantly better than students who were exposed to the opaque cueing or the transparent cueing treatment. These results were confirmed by the mental effort scores. Students who received semi-transparent cueing treatment expended less mental effort than students who received opaque cueing or transparent cueing treatment.

The lack of a difference between the semi-transparent group and each of the opaque and the transparent groups in the achievement scores may be due to the nature of the achievement test items. For example, some of the questions asked the students to identify the name of the menu they used to add a picture to a presentation or to make a hyperlink. These kinds of questions are difficult and confusing if the students are not presented with the actual software. In the case of having the actual software, students would be able to navigate and explore the different menus until they find the needed menu. In addition, the transparent cueing that was used in the transparent cueing treatment (transparent background for the text message box) was not strong in guiding students' attention. Students dealt with this cue as a part of the instruction because the students did not distinguish the cue from the instruction itself. Accordingly, this cue failed to guide students' visual search, which resulted in a split attention effect. The difference between the semi-transparent cueing group and the opaque cueing group in the performance test and mental effort scores indicates that using opaque cueing strategies resulted in successive instruction. Students were not able to see part of the animation whenever the opaque cue was presented, but the use of semi-transparent cueing strategies resulted in concurrent instruction. Students were able to see both the cue and the animation at the same time. These results indicated that students in the opaque cueing group were unable to build referential connections, but the students in the semi-transparent cueing group were able to make referential connections.

In addition, students in the opaque cueing group performed significantly higher in the performance test scores than students in the transparent cueing group. As mentioned before, the cueing effect in the transparent group failed in guiding students' visual attention as the cue was very similar to the instruction itself. However, using the opaque cue guided students' attention, which resulted in eliminating the visual search.

The same results were revealed from Experiment 2 (PowerPoint topic), which provided robustness for the results of this study except for one difference. Students in the opaque cueing group did not score significantly higher in the performance test than students in the transparent cueing group. This result was very interesting, and the investigator did not expect a difference between Experiment 1 and Experiment 2. This difference may be due to another factor that the investigator did not take into account or did not observe until comparing the results of the two experiments: students in Experiment 2 (PowerPoint topic) were more experienced students than students in Experiment 1 (Dreamweaver topic). This difference between the two experiments may be due to the fact that students in Experiment 2 were more experienced students than students in Experiment 1.

Concerning low- and high-spatial-ability students, according to the view of spatial ability of the learners, low-spatial-ability students must devote more cognitive resources to build visual representational connections during learning than do high-spatial-ability students (Mayer & Sims, 1994). This building representational and referential connection is needed for understanding, and it is enabled by concurrent (semi-transparent cueing) rather than successive presentation (opaque cueing). According to this view, neither high- nor low-spatial ability students are able to build referential connections when verbal information and visual information are not presented at the same time. As predicted by this view, high-spatial-ability students who received semi-transparent cueing scored significantly better in the performance test and spent less mental effort than students who received opaque cueing or transparent cueing. There was no difference among high-spatial-ability students in the achievement test score. Also, low-spatial-ability students who received semi-transparent cueing scored significantly higher on the performance test and spent less mental effort than students who received opaque cueing or transparent cueing. These results yielded a pattern in which semi-transparent cueing significantly benefited both high and low spatial abilities.

Instructional Implications of the Study

This study advances the understanding of how to help students integrate verbal and visual information presented in multimedia environments. The findings of this study are consistent with the hypothesis that multimedia instruction is enhanced when students are able to hold representations of the salient verbal and visual information in working memory at the same time. In this case, students are more able to construct referential connections between salient visual and verbal information. This situation is maximized by concurrent presentation (using semi-transparent cues) and is minimized by successive presentations (using opaque cues). Also, this study calls attention to the need to broaden the goals of instructional designers, educators, and developers of multimedia instruction. Their role requires an understanding of human cognitive structures and the instructional design principles that flow from them.

The present study offers some theoretical and practical implications. On the practical side, it provides implications relevant for the display design of multimedia instruction. According to the results of this study, it is vital to pay attention to the state of objects that are used to guide students' attention. This study suggests that semi-transparent cues eliminate visual search by providing students with cues to guide their visual attention and at the same time reduce split attention since semi-transparent cues allow the appearance of the animation in the background. Also, in the design of multimedia instruction, the designer is faced with the need to compress the materials into a relatively small area of the computer screen (Moreno & Mayer, 1999). This study provides a new effective technique to present different sources of information in this small area of the student's visual field (computer screen) which is using semi-transparent objects. In designing instructional software, it is vital to physically integrate salient visual and verbal information in multimedia instruction. On the theoretical side, this study provides evidence concerning the moderating effect of individual differences, particularly spatial ability on the learners' cognitive load in multimedia learning. In addition, it has been shown that learning is impaired when using an opaque cueing strategy, consistent with previous research that used successive versus concurrent instruction (Moreno & Mayer, 1999). This study was an aid to determine research-based principles for how to design multimedia materials in a way that reduces split attention.

The results of this study are inconsistent with Mautone and Mayer's (2001) research in using signaling with animation, which failed to obtain an animation-signaling effect. The signaling (cueing) that Mautone and Mayer used in their study was in the form of colored arrows, which did not adequately guide the learning process. Compared to the results of Mautone's study, using signaling or cueing in this study was effective only in the semi-transparent group. The failure of obtaining an animation signaling effect in Mautone's study may have been due to using opaque objects to guide students' attention, which overloaded working memory and did not reduce the split attention effect.

This study suggests that designers and instructors should pay special attention to interface design in multimedia instruction. The findings from this study may have implications for designing and presenting distance education via the Internet. The results of this study may assist interface designers in their decisions regarding what objects should be opaque and what objects should be semi-transparent.

Limitations and Future Directions

This study is limited by the nature of the materials, the participants, and the learning measures. First, the instructional materials concentrated on learning electronic tools because learning electronic tools using screen capture animation involves a large amount of visual search from students. Additional research is needed to evaluate the robustness of the results using different types of information, for example, scientific information. Second, the participants in this study were mostly female college students; additional research is needed in more diverse settings. Third, the learning measures focused on achievement, performance, and subjective mental effort scale. The same results may not be achieved for other kinds of learning measures such as retention, problem-solving, and objective mental effort measures.

The investigator noted that while applying the treatment, students wanted to work more on the performance test while building a webpage using Dreamweaver or creating a presentation using PowerPoint. But due to the time limit of the class period, they were asked to upload the products they created by the end of the class period time. Additional research is needed to observe what results would be obtained by not limiting the time and letting students finish the performance test at their own pace. Also, the investigator planned to have each student who was exposed to Experiment 1 also be exposed to Experiment 2 and make correlations between the two experiments. However, due to the series of hurricanes that happened while applying the treatment, the investigator was prevented from achieving this goal as many of the students missed attending the classes. Many of these students participated in the two experiments.

Future research is needed to determine whether different cueing strategies would produce deeper learning in long-term memory, delayed testing and authentic learning environments. Better quality achievement test items that measure higher cognitive abilities are needed. Also, measures for retention and problem-solving skills need to be tested as well. This study looked at the effects of split attention on high- and low-spatial-ability students, but more studies are needed to measure the effects of split attention on students with different cognitive styles.

Students in Experiment 2 (PowerPoint treatment) were more experienced with the topic than the students in Experiment 2 (Dreamweaver treatment), and they performed better in the pretests. Also, the opaque group in Experiment 1 scored significantly higher than the transparent group; however, there was no significant difference between the opaque group and the transparent group in Experiment 2. Studies are needed to take into account the experience level of the students. Testing the effects of using a semi-transparent design is needed in different components of the multimedia instruction (i.e., studies that concentrate on testing the role of animated agents in improving multimedia instruction can compare the use of opaque animated agents versus semi-transparent or transparent animated agents and/or backgrounds).

Conclusion

Working memory is limited with the amount of information that can be processed at any given time and also is limited on the time that this information can be held in working memory. Cognitive load theory assumed that information presented to the students should be designed to reduce any cognitive load in working memory. This study was designed to test a way of avoiding cognitive overload due to the split attention effect that occurs when learning from two salient sources of information (verbal and visual). Split attention occurs when students need to mentally integrate visual and verbal information for understanding. It was demonstrated in a number of previous studies that if the multiple sources of information are physically integrated, understanding can occur without an unnecessary search for relations between those sources of information. For this information to be integrated, mental representations of that information must be held in working memory at the same time. The current study used text message boxes to provide critical information to students while learning how to create a PowerPoint presentation or how to create a webpage using Dreamweaver. This text message box also served as a cue to guide students' attention. Students need to integrate the critical information with the animation for better understanding.

The result of this study demonstrated that semi-transparent cueing groups outperformed the other two groups (transparent cueing and opaque cueing). The use of semi-transparent cues allowed the critical information and animation to appear at the same time providing a concurrent presentation rather than a successive one. This situation allowed representations from the verbal and visual information to be held in working memory at the same time which facilitated their integration process

APPENDIX A
DREAMWEAVER ACHIEVEMENT TEST

Student's Name: **College:** **Major:** **Year in the Program:**	**Computer Number:** (This number is written on a red sticker on your computer monitor) **Age:** **Gender:**

Please answer the following questions by selecting one of the following answers: a, b, c, or, d.

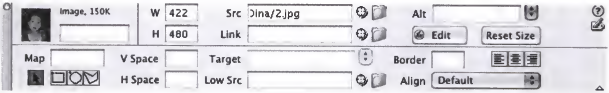
1. **To create an external link from your webpage pointing to the College of Education website, what is the correct URL?**
    a. coe.ufl.edu
    b. http://www.coe.ufl.edu
    c. http://coe.ufl.edu
    d. www.coe.ufl.edu

2. **Which menu would you use to add an image to your webpage?**
    a. The Modify Menu
    b. The Insert Menu
    c. The View Menu
    d. The Edit Menu

3. **After inserting an image, which of the following cannot be changed within Dreamweaver?**
    a. Height
    b. Width
    c. Resolution
    d. Alignment

4. **To change the background color of a webpage, you should**
    a. Hold the Control key and click the mouse in the Document Window and choose Page Properties
    b. Use the Properties Toolbar
    c. Use the Modify Menu
    d. A and C

5. **When the Properties Toolbar looks like the picture below, it means**


Image, 150K
W 422
H 480
Src)ina/2.jpg
Align Default

    a. A text is selected
    b. A picture is selected
    c. A table is selected
    d. A table cell is selected

6. **To create an email link to yourname@ufl.edu, what is the correct command?**
    a. mail to:yourname@ufl.edu
    b. mail to: yourname@ufl.edu
    c. mailto:yourname@ufl.edu
    d. mailto: yourname@ufl.edu

7. **One way to add a table into the your webpage is to choose**
    a. Insert > Table from the menu bar
    b. The Table icon from the Properties Toolbar
    c. Modify > Table from the menu bar
    d. View > Table View from the menu bar

8. **You use the preview mode in Dreamweaver to**
    a. Test your webpage
    b. Edit your webpage

  c. Upload your webpage
  d. Save your webpage

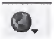
9. Why should your webpage include a title?

  a. So that search engines can index your webpage
  b. To allow users to see where they are in your site
  c. To allow users to bookmark your webpage easily
  d. All of the above

10. When you use image and other media in your webpage, these media files must be located in

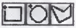
  a. The same folder as your webpage file
  b. Anywhere in the computer; it does not matter
  c. A Zip disk
  d. A CD-ROM

11. Which icon do you click to merge cells in a table?

a. 

b.

c.

d. 

12. To set the space between each table cell to 12 pixels, which table attribute would you have to use from the Properties Toolbar?

  a. Border
  b. Width
  c. Cell spacing
  d. Cell padding

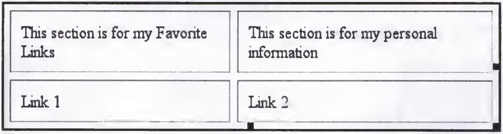
13. How do you know that the border of a table has been set to 0 in the Document Window while working in Dreamweaver?

a. The border will disappear completely
b. The border will appear as a faint broken line
c. The border will change to red
d. The border will appear as a fine line

14. Everyone who has a web browser connected to the Internet can see your webpage when you

a. Save your webpage to your computer
b. Preview your webpage in Dreamweaver
c. Upload your webpage to a host
d. Edit your webpage using Dreamweaver

15. When a table looks like the following picture, it means



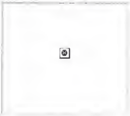
This section is for my Favorite Links	This section is for my personal information
Link 1	Link 2

a. The table is Cell Padded
b. The table is Cell Spaced
c. A and B
d. The table has a value of 0 borders

16. You can test the email link you created in your webpage when you

a. Preview your webpage in Dreamweaver
b. Upload your webpage to a host
c. Save your webpage
d. A and B

17. When you uploaded your webpage, you found that the picture you inserted gave you a broken image link like the picture below. This might be because



a. You forgot to upload the picture with your webpage file
b. The picture file name is incorrect
c. The picture had a wrong path
d. All of the above

18. Which attribute can you apply for the entire table and not for an individual cell?

a. Border
b. Height and width
c. Background color
d. Text color

19. When you name your webpage, the name should

a. Be short
b. Have no spaces and no capital letters
c. Have no punctuation
d. All of the above

20. Which key would you use to resize an image while keeping its proportions?

a. Option key
b. Apple key
c. Shift key
d. Control Key

APPENDIX B
POWERPOINT ACHIEVEMENT TEST

Student's Name: **College:** **Major:** **Year in the Program:**	**Computer Number:** (This number is written on a red sticker on your computer monitor) **Age:** **Gender:**

Please answer the following questions by selecting one of the following answers: a, b, c, or, d.

1. **Which menu would you use to add a new slide to your presentation?**
   - a. Format menu
   - b. Tools menu
   - c. Insert menu
   - d. Slide Show menu

2. **Which of the following features changes words to drawing objects?**
   - a. ClipArt
   - b. AutoShape
   - c. Chart
   - d. WordArt

3. **Which view displays your slides as a presentation?**
   - a. Slide Show view
   - b. Outline view
   - c. Normal view
   - d. Slide view

4. PowerPoint has four views that you use while you are creating a presentation. To display all the slides in your presentation at the same time, what view do you use?

a.

b.

c.

d.

5. What is the name of the area where you create, edit, and display slides?

a. Outline

b. Slide

c. Notes

d. Task

6. The text below has been formatted. Which of the buttons below was clicked to format this text?

I have learned
PowerPoint and
I am so Proud of myself

a.

b.

c.

d.

7. **To add a custom animation effect to a selected element in a slide, which menu do you use?**
   a. Slide Show
   b. Tools
   c. Insert
   d. Format

8. **Normal view is composed of the**
   a. Outline pane and the slide pane
   b. Sorter pane and the slide pane
   c. Sorter pane, the slide pane, and the show pane
   d. Outline pane, the slide pane, and the notes pane

9. **The custom animation allows you to**
   a. Control animation on an object-by-object basis
   b. Control animation on a slide-by-slide basis
   c. Set slide transitions
   d. Add action buttons to your presentation

10. **To preview the hyperlink you inserted to a slide in a presentation, which view do you use?**
    a. Normal view
    b. Slide Show view
    c. Slide Sorter view
    d. Slide view

11. You have created a presentation that includes a chart in one of its slides. How do you make changes to that chart?

a. By Clicking Chart Options on the Chart Menu

b. By double-clicking on the chart in the slide

c. By choosing Chart from the Format Menu

d. By opening the Master Slide, and clicking Chart Type on the Chart Menu

12. When you save your PowerPoint presentation, what file extension is used for a presentation file created in PowerPoint?

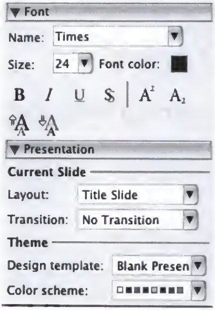
a. doc

b. ppt

c. txt

d. pps

13. What is the name of the following Palette?



Name: Times

Size: 24

Layout: Title Slide

Transition: No Transition

Design template: Blank Presen

a. Standard Palette

b. Formatting Palette

c. Common Tasks Palette

d. None of the above

14. When you first open the PowerPoint application, what is displayed?

a. A blank presentation document
b. The last presentation you were working on
c. No presentation
d. None of the above

15. You use File > Update Presentation when you try to insert a

a. Text into your presentation
b. Picture into your presentation
c. Chart into your presentation
d. Media clip into your presentation

16. You can add a hyperlink to a slide using the

a. Edit Menu
b. Slide Show Menu
c. Insert Menu
d. View Menu

17. **The animation effect that happens when the slide show moves from one slide to the next is**

a. Custom Animation
b. ClipArt Animation
c. Text Animation
d. Slide Transition

18. Which view allows you to view small images of all slides?

a. Normal view
b. Outline view
c. Slide Sorter view
d. Slide view

APPENDIX C
DREAMWEAVER LEARNING OBJECTIVES

After learning Dreamweaver, students should be able to:

- Create and rename a folder for storing all webpage materials.
- Use basic pen-and-paper drawing techniques to plan a webpage.
- Name and save your webpage.
- Create tables for the purpose of formatting a webpage.
- Merge cells in tables.
- Insert pictures into a webpage.
- Add and format text in a webpage.
- Adjust page properties for a webpage.
- Format the color, cell padding, and cell spacing of tables in a webpage.
- Create external links in a webpage.
- Create email links in a webpage.
- Preview a webpage before uploading it.

APPENDIX D
POWERPOINT LEARNING OBJECTIVES

After learning PowerPoint, students should be able to:

- Open up a blank presentation in PowerPoint.
- Access the Formatting Palette in PowerPoint.
- Access the Standard and Formatting Toolbars in PowerPoint.
- Insert new slides into a PowerPoint presentation.
- Use various layouts in PowerPoint (bulleted list, text and two pictures, text and media clip, etc.).
- Add text to a PowerPoint presentation.
- Insert WordArt into a PowerPoint Presentation.
- Insert pictures into a PowerPoint Presentation.
- Insert an organizational chart into a PowerPoint presentation.
- Insert a Movie clip into a PowerPoint presentation.
- Add sound files to a PowerPoint presentation.
- Insert hyperlinks into a PowerPoint Presentation.
- Apply design templates to a PowerPoint presentation.
- Add slide transitions to a PowerPoint presentation.
- Save a PowerPoint presentation.

APPENDIX E
DREAMWEAVER TASK PERFORMANCE TEST

Student's Name:	**Computer Number:** (This number is written on a red sticker on your computer monitor)

Use the following directions to create a webpage using Dreamweaver Mx. You are free to format your webpage the way you like and use your own pictures, but your webpage must have the following:

1. A background color other than the default
2. At least two pictures
3. Five different categories (for example, Favorite Movies, Favorite Music, Favorite Songs, etc. You are free to use your own categories that you might like to include in your personal page)
4. A title for your webpage (e.g., JoeCool's personal page)
5. At least one table to lay out your page, use the following values for the table:
    a. Two rows and two columns
    b. (640) Pixels for the table width
    c. (3) Pixels for cell padding
    d. (4) Pixels for cell spacing
    e. (0) Pixels for borders
6. Two different fonts, two different font sizes and two different font colors to format the text in your page
7. At least one external link on your webpage (e.g., a link to your favorite website)
8. An email link
9. Save your personal page using your first name and last name (e.g., joecool.html). Save it to a folder name using your first and last name as well on the desktop.

After you save your webpage, upload it along with any media you used to the server using Fetch and the following information:

Host: www.ep.coe.ufl.edu

User ID: student

Password: student

Note that when you log into Fetch, you will find folders that are named with the day and the period of your class session (e.g., M7, T4, R5), where M7 stands for Monday, Period 7, T4 stands for Tuesday, Period 4, and R5 stands for Thursday, Period 5. Double click on the folder that signifies your class meeting time. Inside this folder you will find another folder that is named with your first name and last name. Locate this folder and double click on it. Then drag your webpage file and any other media files you used in your webpage from your desktop to Fetch.

Thank you!

APPENDIX F
POWERPOINT TASK PERFORMANCE TEST

Student's Name:	**Computer Number:** (This number is written on a red sticker on your computer monitor)

Use the following directions to create a presentation using PowerPoint. Your final presentation should contain the following information (remember to save your presentation to the desktop using your first name and last name as the first step):

1. At lease five slides
2. At least one picture
3. A table
4. An organizational chart
5. A hyperlink
6. Slide transitions between all your slides
7. Custom animation within at least one of your slides
8. A sound effect
9. At least two different text fonts, two different font colors and two different font sizes
10. Save your presentation on the desktop. Use your first and last name when naming your presentation (e.g., JoeCool.ppt)

You are free to choose the topic of your presentation.

After you save your presentation, upload it to the server using Fetch and the following information:

Host: www.ep.coe.ufl.edu

User ID: student

Password: student

Note that when you log into Fetch, you will find folders that indicate the day and the period of your class session (e.g., M7, T4, R5), where M7 stands for Monday, Period 7, T4 stands for Tuesday, Period 4, and R5 stands for Thursday, Period 5. Double click on the folder that represents your class meeting time. Inside this folder you will find another folder that is named with your first name and last name. Locate this folder and double click on it. Then drag the presentation you created from the desktop to Fetch.

Thank you!

APPENDIX G
RUBRIC FOR GRADING DREAMWEAVER TASK PERFORMANCE TEST

(TOTAL POINTS: 17)

Criteria	Unsatisfactory (No Credit)	Needs Improvement (Partial Credit)	Excellent (Full Credit)
Student named the personal page file correctly. 1 point			
Student created and named a folder on the desktop correctly. 1 point			
Student used two different fonts to format the text. 1 point			
Student used two different font sizes to format the text. 1 point			
Student used two different font colors to format the text. 1 point			
Student titled his webpage. 1 point			
Student used at least one table to format the page's content. 1 point			
Student used at least two rows for the layout table. 1 point			
Student used at least two columns for the layout table. 1 point			
Student inserted at least two pictures into the page. 1 point			
Student used the value (640) for the table width in pixels. 1 point			

Student used the value (4) for cell padding. 1 point			
Student used the value (0) for the table border. 1 point			
Student included at least five categories of information about himself. 1 point			
Student included at least one external link. 1 point			
Student included an email link. 1 point			
Student changed the background color of the page. 1 point			

APPENDIX H
RUBRIC FOR GRADING POWERPOINT TASK PERFORMANCE TEST

(TOTAL POINTS: 12)

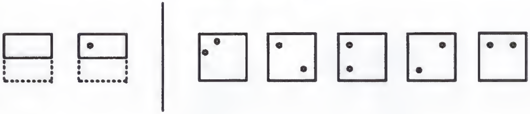
Criteria	Unsatisfactory (No Credit)	Needs Improvement (Partial Credit)	Excellent (Full Credit)
Student included at least five slides. 1 point			
Student inserted at least one picture. 1 point			
Student used at least one diagram, organizational chart, or table. 1 point			
Student inserted at least one Hyperlink. 1 point			
Student used a design template to give the presentation a professional look. 1 point			
Student included transitions among all the slides. 1 point			
Student used custom animation in at least one slide. 1 point			
Student inserted sound into at least one slide. 1 point			
Students used at least two different text fonts to format the text. 1 point			
Student used at least two different font sizes to format the text. 1 point			
Student used at least two different font colors to format the text. 1 point			

Student named his presentation using his first and last name and saved it to the desktop. 1 point			

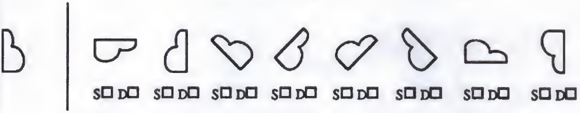
APPENDIX I

SAMPLE QUESTIONS FROM THE PAPER FOLDING AND CARD ROTATIONS SPATIAL ABILITY MEASURES

Paper Folding



Card Rotations



APPENDIX J
MENTAL EFFORT SCALE

Student's Name:

Please circle the number that most accurately describes the mental effort you invested while learning the instructional materials.

In studying the preceding instruction I invested

1. very, very low mental effort
2. very low mental effort
3. low mental effort
4. rather low mental effort
5. neither low nor high mental effort
6. rather high mental effort
7. high mental effort
8. very high mental effort
9. very, very high mental effort

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BIOGRAPHICAL SKETCH

Before attending the University of Florida in Gainesville, I was employed as a full-time instructor in the College of Education, Minia University, Egypt, where I taught courses in educational technology from 1993 to 1999. I also taught educational technology courses in the College of Specific Education, Minia University, Egypt. In the fall of 1999, I enrolled at the University of Florida, where I specialized in educational technology, which included curriculum and educational system designs, performance technology, information-based teaching, problem-based teaching, assessment design, and other related disciplines.

I worked as a research assistant from 2000 to 2004 in the Office of Educational Technology in the College of Education at the University of Florida. I was responsible for teaching faculty development workshops, consulting with faculty and teaching assistants to help them integrate technology into their teaching, and also helping pro-teach students developing their electronic portfolios. In addition, I developed many online tutorials to support faculty and students: http://www.coe.ufl.edu/oit

I also was a graduate assistant from 2004 to present in the School of Teaching and Learning. I was responsible for helping faculty develop their online courses for the new online master's program.

While attending the University of Florida, I was presented with two awards: one for "Best Achievement by an International Student" from the International Student Center and the other one for "Outstanding Academic Accomplishment" from the College of Education.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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